PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

BJERKÉN, Håkan
Bjerkéns Patentbyrå KB
P.O. Box 1274
S-801 37 Gävle
SUÈDE

Date of mailing (day/month/year) 16 September 1999 (16.09.99)	
Applicant's or agent's file reference PCT 14205HB le	**IMPORTANT NOTIFICATION**
International application No. PCT/SE98/01733	**International filing date** (day/month/year) 29 September 1998 (29.09.98)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
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	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

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ABB AB S-721 83 Västerås Sweden	SE	SE
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Eugénia Santos Telephone No.: (41-22) 338.83.38

30 -09- 1998

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/ SE 98 / 01733

International Filing Date 29 -09- 1998

The Swedish Patent Office PCT International Application

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* PCT 14205HB le

Box No. I TITLE OF INVENTION

"Electromagnetic device"

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

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☐ This person is also inventor.

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Teleprinter No.

State *(that is, country)* of nationality: Sweden

State *(that is, country)* of residence: Sweden

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

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This person is:

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☒ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Sweden

State *(that is, country)* of residence: Sweden

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BJERKÉNS PATENTBYRÅ KB, represented by BJERKÉN, Håkan; OLSSON, Jan; BERGLUND, Stefan or FRÖDERBERG, Oskar
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☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

CONFIRMATION COPY

See Notes to the request form

CANCELLED EX OFFICIO BY IB

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes: at least one must be marked)*:

Regional Patent

☒ **AP** **ARIPO Patent: GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SZ** Swaziland, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent: AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent: AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent: BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

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☒ **SG** Singapore
☒ **SI** Slovenia
☒ **SK** Slovakia and utility model
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Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

☐ ....
☐ ....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

PCT/ SE 98 / 01733

Sheet No. ...3....

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application *(day/month/year)*	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) November 26, 1997	9704392-1	Sweden		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): ______

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

RO/SE

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*:

ISA / SE

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority)*:

Date *(day/month/year)*	Number	Country *(or regional Office)*
4 February, 1998	SE 98/00048	Sweden

RO/SE

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	:	3 ✓
description (excluding sequence listing part)	:	24 ✓
claims	:	5 ✓
abstract	:	1 ✓
drawings	:	8 ✓
sequence listing part of description	:	
Total number of sheets	:	41 ✓

This international application is **accompanied by** the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*:

Figure of the drawings which should accompany the abstract: (1)

Language of filing of the international application:

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Gävle, September 29, 1998
Bjerkéns Patentbyrå KB

....
Håkan Bjerkén

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1. Date of actual receipt of the purported international application:	29 -09- 1998	2. Drawings: ☒ received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:		☐ not received:
4. Date of timely receipt of the required corrections under PCT Article 11(2):		
5. International Searching Authority (if two or more are competent): ISA / SE	6. ☐ Transmittal of search copy delayed until search fee is paid.	

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Date of receipt of the record copy by the International Bureau: 16 OCTOBER 1998 (16. 10. 98)

hb/ij SE14205

Sökande: Asea Brown Boveri AB

ELEKTROMAGNETISK ANORDNING

UPPFINNINGENS OMRÅDE OCH TIDIGARE TEKNIK

Denna uppfinning avser en elektromagnetisk anordning innefattande åtminstone en magnetkrets och åtminstone en elektrisk krets innefattande åtminstone en lindning, varvid de magnetiska och elektriska kretsarna är induktivt kopplade till varandra och varvid anordningen innefattar en reglerinrättning för att reglera funktionen hos anordningen.

Denna elektromagnetiska anordning kan nyttjas i vilka som helst elektrotekniska sammanhang. Effektområdet kan vara från VA upp till 1000 MVA-området. Primärt avses högspänningstillämpningar upp till de högsta överföringsspänningar som används idag.

Enligt en första aspekt av uppfinningen avses en roterande elektrisk maskin. Sådana elektriska maskiner innefattar synkronmaskiner som huvudsakligen används som generatorer för anslutning till distributions- och transmissionsnät, nedan gemensamt kallade kraftnät. Synkronmaskinerna används också som motorer samt för faskompensering och spänningsreglering, då som mekaniskt tomgående maskiner. Det tekniska området innefattar även dubbelmatade maskiner, maskiner av typen asynkron strömriktarkaskad, ytterpolmaskiner, synkronflödesmaskiner och åssynkronmaskiner.

Enligt en annan aspekt av uppfinningen utgörs nämnda elektromagnetiska anordning av en krafttransformator eller reaktor. Vid all överföring och distribution av elektrisk energi ingår transformatorer. Deras uppgift är att medge utbyte av elektrisk energi mellan två eller flera elsystem och för detta nyttjas elektromagnetisk induktion på i och för sig väl känt sätt. De transformatorer som primärt avses med föreliggande uppfinning tillhör de så kallade krafttransformatorerna med märkeffekt från något hundratal kVA upp till över 1000

medför begränsningar vad gäller lindningarnas placering vid magnetkretsen.

SAMMANFATTNING AV UPPFINNINGEN

Syftet med föreliggande uppfinning är att anvisa utvägar att förenkla och förbättra möjligheterna att reglera funktionen hos elektromagnetiska anordningar enligt ingressen till efterföljande patentkrav 1, varjämte bättre förutsättningar för rationell lindningsproduktion och -montering skall skapas.

Det grundläggande syftet med föreliggande uppfinning uppfylles genom att reglerinrättningen är anordnad att reglera frekvens, amplitud och/eller fas vad avser elektrisk energi till/från anordningen genom att reglerinrättningen innefattar organ för reglering av det magnetiska flödet i magnetkretsen.

Föreliggande uppfinning baserar sig följaktligen på idén att genom flödesreglering direkt påverka det magnetiska flödet i magnetkretsen i önskat avseende för att därigenom kunna reglera anordningens funktion. Därmed erhålles ett mycket rationellt och kostnadseffektivt utförande, varjämte erbjuder sig ökade möjligheter till reglering i och för uppnående av en optimerad drift.

Enligt ett speciellt föredraget utförande av uppfinningen innefattar reglerorganet minst en till magnetkretsen induktivt kopplad reglerlindning. Via reglerlindningen är följaktligen reglerinrättningen kapabel att effektuera erforderlig reglering av magnetflödet i magnetkretsen genom att via reglerlindningen applicera sådana reglerparametrar att det i magnetkretsen flytande magnetflödet påverkas i erforderlig utsträckning. Reglerlindningen skulle till och med kunna kortslutas. Magnetflödet kan då i vissa utföranden icke passera reglerlindningen. I beroende av magnetkretsens utförande kan partiell eller total blockering av magnetflödet uppstå.

Exempel på styrfunktioner som kan uppnås med den uppfinningsenliga lösningen är spänningsförändring och -stabilisering, eliminering av transienter, dämpning av oscillationer i kraftnätet,

Vad gäller uppfinningen i dess skepnad av roterande elektrisk maskin skapas därmed förutsättningar för att driva maskinen med så hög spänning att konventionella "step up"-transformatorer kan uteslutas. Maskinen kan således drivas med väsentligt högre spänning än maskiner enligt teknikens ståndpunkt för att utföra direktanslutning till elkraftnät. Detta medför väsentligt lägre investeringskostnader för system med en roterande elektrisk maskin och systemets totala verkningsgrad kan ökas. Uppfinningen eliminerar behovet av särskilda fältstyrningsåtgärder vid vissa områden av lindningen, vilka fältstyrningsåtgärder varit nödvändiga enligt tidigare teknik. En ytterligare fördel är att uppfinningen gör det lättare att åstadkomma under- och övermagnetisering i ändamål att reducera reaktiva effekter uppkommande när spänning och ström är ur fas med varandra.

Vad beträffar uppfinningsaspekten som krafttransformator/ reaktor eliminerar uppfinningen framför allt behovet av oljefyllning av krafttransformatorerna och därav följande problem och nackdelar.

Utformningen av lindningen så att den utmed åtminstone en del av sin längd innefattar en isolering bildad av ett fast isoleringsmaterial, innanför denna isolering ett inre skikt och utanför isoleringen ett yttre skikt med dessa skikt av halvledande material skapar möjlighet att innehålla det elektriska fältet i hela anordningen inom lindningen. Med det här använda uttrycket "fast isoleringsmaterial" avses att lindningen skall sakna vätske- eller gasformig isolering, till exempel i form av olja. Istället avses isoleringen vara bildad av ett polymert material. Också det inre och yttre skiktet är bildade av ett polymert material, dock ett halvledande sådant.

Det inre skiktet och den fasta isoleringen är fast förbundna med varandra över väsentligen hela gränsytan. Även det yttre skiktet och den fasta isoleringen är fast förbundna med varandra över väsentligen hela gränsytan däremellan. Det inre skiktet fungerar potentialutjämnande och därmed utjämnande vad avser det elektriska fältet utanför det inre skiktet som en konsekvens av dess halvledande egenskaper. Det yttre skiktet avses likaledes vara utformat av ett halvledande material och har åtminstone en elektrisk konduktivitet

upphov till någon destruktion eller söndring i gränsytorna. Således säkerställs intim vidhäftning i kontaktytan mellan de inre och yttre skikten och den fasta isoleringen och förutsättningar för att vidmakthålla denna vidhäftning under långa driftsperioder. Vidhäftningen skall vara av den arten att vidhäftningen mellan åtminstone det i det inre skiktet och den fasta isoleringen och företrädesvis också det yttre skiktet och den fasta isoleringen säkerställes också vid de böjningar som den elektriska ledningen och isolationssystemet kommer att underkastas. Det påpekas här att kabeln för att kunna utföra trädningen av lindningen bör vara böjlig i en krökningsradie som är mindre än 25 gånger kabeldiametern, företrädesvis mindre än 15 gånger kabeldiametern. Det mest föredragna är att kabeln är böjlig ned till en krökningsradie som är mindre än eller väsentligen lika med 8 gånger kabeldiametern.

Det är väsentligt att isolationssystemet består av material med en god elasticitet. Materialens E-modul bör vara förhållandevis låg, det vill säga att materialens deformationsmotstånd skall vara förhållandevis lågt. För att undvika att i gränszonen mellan olika skikt ingående i isolationssystemet äventyrliga skjuvspänningar uppstår föredrages att elasticiteten (E-modulen) hos de i isolationssystemet ingående skikten är väsentligen lika.

Den elektriska belastningen på isolationssystemet minskar som en följd av att de av halvledande material bestående inre och yttre skikten kring isoleringen kommer att tendera att utgöra väsentligen ekvipotentiella ytor och att därigenom det elektriska fältet i själva isoleringen kommer att fördelas relativt jämnt över isoleringens tjocklek.

Det är känt att högspänningskablar för överföring av elektrisk energi kan vara uppbyggda av ledare med en isolering av ett fast isoleringsmaterial med inre och yttre skikt av halvledande material. Vid överföring av elektrisk energi så har man sedan länge tagit fasta på att isoleringen skall vara fri från defekter. Vid högspänningskablar för transmission ändras dock ej den elektriska potentialen utmed kabelns längd utan potentialen ligger i princip på samma nivå. Dock kan även vid högspänningskablar för transmissionsbruk uppstå

En sådan böjlig lindningskabel som kommer till användning enligt föreliggande uppfinning vid dess elektromagnetiska anordning är en vidareutveckling av den i och för sig för transmissionsändamål använda PEX-kabeln eller en kabel med EP-gummiisolation. Vidareutvecklingen innefattar bland annat ett nytt utförande både vad den elektriska ledarens parter beträffar och också att kabeln, åtminstone vid vissa utföranden, icke avses ha något yttre hölje för mekaniskt skydd av kabeln. Dock är det möjligt enligt uppfinningen att utanför det yttre halvledande skiktet anordnas en ledande metallskärm och en yttre mantel. Metallskärmen kommer därvid att erhålla karaktären av yttre mekaniskt och elektriskt skydd, exempelvis mot åsknedslag. Det föredrages att det inre halvledande skiktet kommer att ligga på den elektriska ledarens potential. För detta ändamål avses åtminstone en av den elektriska ledarens kardeler vara oisolerad och så anordnad att god elektrisk kontakt åstadkommes med det inre halvledande skiktet. Alternativt kan olika kardeler vara växelvis ledande med elektrisk kontakt mot det inre halvledande skiktet. Att tillverka transformator- eller reaktorlindningar av en böjlig kabel enligt ovan innebär drastiska skillnader vad gäller den elektriska fältfördelningen mellan konventionella krafttransformatorer/reaktorer och en krafttransformator/reaktor enligt uppfinningen. Den avgörande fördelen med en kabelformad lindning enligt uppfinningen är att det elektriska fältet är inneslutet i lindningen och att det således inte finns något elektriskt fält utanför det yttre halvledande skiktet. Det av den strömförande ledaren åstadkomna elektriska fältet uppträder endast i den fasta huvudisoleringen. Både ur konstruktions- och tillverkningssynpunkt innebär det väsentliga fördelar:

- Transformatorns lindningar kan utformas utan att behöva ta hänsyn till någon elektrisk fältfördelning och den under teknikens ståndpunkt omtalade transformeringen av parter bortfaller.

- Transformatorns kärnkonstruktion kan utformas utan att behöva ta hänsyn till någon elektrisk fältfördelning.

Ovan har nämnts hurusom den fasta isoleringen och de inre och yttre skikten kan åstadkommas genom exempelvis extrudering. Andra tekniker är emellertid också väl möjliga, exempelvis bildning av dessa inre och yttre skikt respektive isoleringen med hjälp av påsprutning av materialet ifråga.

Det föredrages att lindningskabeln utformas med ett cirkulärt tvärsnitt. Dock kan också andra tvärsnitt komma till användning i fall där man önskar erhålla bättre packningstäthet.

För att bygga upp spänning i den roterande elektriska maskinen läggs lindningskabeln i flera på varandra följande varv i spår i magnetkärnan. Lindningen kan utföras såsom en flerskiktad koncentrisk kabellindning för att minska antalet härvändskorsningar. Kabeln kan utföras med trappad isolation för att bättre utnyttja magnetkärnan, varvid spårens utformning också kan anpassas till lindningens avtrappade isolation.

En väsentlig fördel vid uppfinningens tillämpning vid en roterande elektrisk maskin är att det elektriska fältet är nära noll i härvändsregionen utanför den yttre halvledaren och att med jordpotential på det yttre halvledande skiktet behöver inte det elektriska fältet styras. Detta innebär att man inte kan få några fältkoncentrationer varken inom kärnan, i härvändsregioner eller i övergången mellan dessa.

Vid ett förfarande för tillverkning av en anordning enligt uppfinningen utnyttjas såsom lindning en böjlig kabel som träds in i öppningar utformade i spår i en magnetisk kärna hos den roterande elektriska maskinen. Kabelns böjlighet medför att en kabellängd kan förläggas i flera varv i en härva. Härvändarna kommer då att utgöras av böjzoner hos kablarna. Kabeln kan även skarvas på så sätt att dess egenskaper förblir konstanta över kabellängden. Detta förfarande innebär väsentliga förenklingar jämfört med teknikens ståndpunkt. De s k röbelstavarna är ej böjliga utan måste förformas till önskad form. Isolerlindning och impregnering av härvorna är också synnerligen komplicerade och dyrbar teknik vid framställning av roterande elektriska maskiner av idag.

fig 7 en axiell ändvy av en sektor/poldelning hos en magnetkrets enligt uppfinningen,

fig 8 en vy visande den elektriska fältfördelningen kring en lindning hos en konventionell krafttransformator/reaktor,

fig 9 en perspektivisk vy illustrerande en utföringsform av en krafttransformator enligt uppfinningen,

fig 10 en tvärsnittsvy illustrerande en relativt fig 1 modifierad kabelstruktur med flera elektriska ledare, och

Fig 11 ett tvärsnitt av en ytterligare kabelstruktur omfattande flera elektriska ledare men i en annan anordning än den i fig 6.

BESKRIVNING AV FÖREDRAGNA UTFÖRANDEFORMER

Den i fig 1 illustrerade elektromagnetiska anordningen har formen av en transformator. Denna uppvisar en magnetkrets 1 och två elektriska kretsar 2, 3 vardera innefattande åtminstone en spolformad lindning 4 respektive 5.

I exemplet illustreras hurusom transformatorn uppvisar en kärna 6av ett magnetiskt material. Kärnan består lämpligen av ett paket av magnetiska skivor för att reducera virvelströmsförluster. Det påpekas emellertid att det icke är någon förutsättning för uppfinningens tillämpning att en kärna verkligen föreligger. Luftlindade utföranden etc är således väl möjliga inom ramen för uppfinningstanken. Härav följer att begreppet magnetkrets skall tolkas i vid bemärkelse. Begreppet ifråga innebär således icke mer än att av förekommande lindningar 4, 5 genererade magnetfält skall vara kapabla att generera ett magnetiskt flöde.

Den uppfinningsenliga anordningen innefattar en generellt med 7 betecknad inrättning för att reglera funktionen hos transformatorn. Denna reglerinrättning 7 är anordnad att reglera frekvens, amplitud och/eller fas vad avser elektrisk effekt som lämnar transformatorn. I

mätningsorgan 11 tjänstgör för strömmätning i sekundärkretsen 3. Tillskottsflödet som genereras via reglerinrättningen 7 kan såsom tidigare nämnts nyttjas för att reglera frekvens, amplitud och/eller fas vad avser den via sekundärkretsen 3 utgående effekten.

Det påpekas att reglerinrättningen 7 kan vara anordnad att via en ingång 12 erhålla externa reglerinstruktioner.

Det påpekas vidare att reglerinrättningen 7 kan vara anordnad att effektuera en passiv reglering via reglerlindningen 9. Med passiv reglering i detta avseende menas att kraft från någon yttre källa icke nyttjas för regleringen. I detta sammanhang påpekas att styrinrättningen 7 kan vara kapabel att över reglerlindningen 9 inkoppla ett eller flera passiva element, såsom resistorer, kapacitanser eller induktanser kopplade i serie eller parallellt. Dylika passiva element kopplade till reglerlindningen 9 på ett för ändamålet anpassat sätt möjliggör således olika inverkningar på det magnetiska flödet, vilka inverkningar i sin tur resulterar i konsekvenser vad beträffar frekvens, amplitud och/eller fas vad avser den elektriska effekten från anordningen.

I fig 1 framgår också hurusom anordningen på primärsidan uppvisar en spänningsmätanordning 13 och en strömmätanordning 14 i likhet med vad som förekommer på sekundärsidan.

I fig 2 illustreras ett transformatorutförande som skiljer sig från det nyss i fig 1 beskrivna blott i det avseendet att den magnetiska kretsen 1 här innefattar en kärna 6 som innefattar ett ytterligare ben 16 utöver det i fig 1 på sekundärsidan förekommande, med 15 betecknade och det på primärsidan förekommande och med 17 betecknade. Detta innebär således att kärnan 6 enligt fig 2 kommer att bilda två olika flödesbanor schematiskt angivna med 18 respektive 19. Reglerlindningen 9a är här anbragt kring det centrala benet 16, det vill säga vid flödesbanan 18, som givetvis genomgår transformatorns primärlindning 4. Den andra flödesbanan 19 däremot passerar förbi reglerlindningen 9a via sekundärlindningen 5. Via reglerinrättningen 7 är det nu möjligt att medelst reglerlindningen 9a påverka magnetflödet i benet 16, vilket i sin tur kommer

I fig 5 illustreras ett synnerligen förenklat generatorutförande, vars rotor är betecknad 26. Denna tänkes i exemplet vara en permanentmagnetsrotor. Det vore emellertid också möjligt att utforma rotorn med fältlindningar. Magnetkretsen 1d uppvisar här en utgående elektrisk krets 5d induktivt kopplad till magnetflödet i kärnan 6d. Kärnan 6d har partier belägna i anslutning till rotorn 26 så att under rotorns rotation permanentmagneterna kommer att generera ett magnetiskt flöde i kärnan. Detta flöde passerar genom den utgående lindningen 5d och alstrar i denna en utgående effekt. Reglerinrättningen 7d innefattar såsom tidigare en reglerlindning 9d induktivt kopplad till magnetkretsen 1d. Mätanordningar 10d respektive 11d för spänning och ström förekommer också här för övervakning av den utgående effekten. Med hjälp av relgerinrättningen 7d kan nu reglerlindningen 9d underkastas för regleringsändamålet erforderlig funktionalitet, passivt eller aktivt i ändamål att bibringa den utgående effekten från generatorn önskade egenskaper med avseende på frekvens, amplitud och/eller fas.

Det betonas att i figurerna ytterst förenklade utförandeformer redovisas och detta närmare bestämt med endast en fas. I realiteten kan utförandena vara väsentligt mer komplicerade, i synnerhet flerfasiga. Antalet lindningar och lindningsdelar kan vara väsentligt större än det som redovisats icke endast vad gäller primär- och sekundärlindningar utan också vad gäller antalet reglerlindningar. Också magnetkretsarna kan ha varierande utförande i beroende av funktionella krav.

Det påpekas speciellt att den omständigheten att enligt uppfinningen åtminstone en av förekommande lindningar inbegriper en elektrisk ledare omgiven av två inbördes åtskilda ekvipotentialskikt och en mellan dessa anbragt, fast isolering innebär att det elektriska fältet kring ledaren kommer att väsentligen inneslutas i kabeln så att primär- och sekundärlindningar med mycket stor frihet kan förläggas var som helst på den magnetiska kretsen. Till och med blandning av lindningarna är möjlig. Det påpekas också i detta sammanhang att reglerinrättningen är tillämpbar för transformatorer både av typen med kärna och skal.

isoleringen 44 saknas således helt isoleringsmaterial av vätske- och gastyp. Detta skikt 44 omges av ett yttre halvledande skikt 45. Den kabel som används som lindning i den föredragna utföringsformen kan vara försedd med metallskärm och yttre mantel men behöver inte vara detta. För att undvika inducerade strömmar och därmed förknippade förluster i det yttre halvledande skiktet 45 skärs detta av, företrädesvis i härvändsutliggningen, dvs i övergångarna från plåtpaket till härvkorg. Avskärningen utföres så att det yttre halvledande skiktet 45 kommer att uppdelas i flera utmed kabeln fördelade, från varandra elektriskt helt eller delvis åtskilda delar. Varje avskuren del ansluts sedan till jord varvid det yttre halvledande skiktet 35 kommer att hållas på eller nästan på jordpotential i hela kabellängden. Detta innebär att kring den fast isolerade lindningen vid härvändarna har de beröringsbara och de, efter viss tids användning, smutsiga ytorna endast försumbara potentialer till jord samt att de även orsakar försumbara elektriska fält.

För att optimera en roterande elektrisk maskin är magnetkretsens utformning vad beträffar spåren respektive tänderna av betydelse. Spåren bör anslutas så nära härvsidornas hölje som möjligt. Det är också önskvärt att tänderna på varje radiell nivå är så breda som möjligt. Detta är viktigt för att minimera maskinens förluster, magnetiseringsbehov m m.

Med tillgång till en ledare för lindningen som den ovan omtalade kabeln finns stora möjligheter att kunna optimera magnetkärnan ur nämnda synpunkter. I det följande refereras till en magnetkrets i den roterande elektriska maskinens stator. I figur 7 visas en utföringsform av en axiell ändvy av en sektor/poldelning 46 hos en maskin enligt uppfinningen. Rotor med rotorpol är betecknad med 47. Statorn är på konventionellt sätt sammansatt av en laminerad kärna av elplåt successivt sammansatt av sektorformade plåtar. Från ett radiellt ytterst beläget ryggparti 48 av kärnan sträcker sig ett antal tänder 49 radiellt in mot rotorn. Mellan tänderna finns ett motsvarande antal spår 50. Användning av kablar 51 enligt ovan medger bl a att spårens djup för högspänningsmaskiner kan göras större än vad som har varit möjligt enligt teknikens ståndpunkt.

Som omtalat ovan kan magnetkretsen befinna sig i den roterande elektriska maskinens stator och/eller rotor. Magnetkretsens utformning kommer dock i stora drag att motsvara ovanstående beskrivning oberoende av om magnetkretsen befinner sig i statorn och/eller rotorn.

Som lindning används företrädesvis en lindning som kan beskrivas som en flerskikts koncentrisk kabellindning. En sådan lindning innebär att antalet korsningar vid härvändorna har minimerats genom att samtliga härvor inom samma grupp har placerat radiellt utanför varandra. Detta medger också ett enklare förfarande vid tillverkningen och trädningen av statorlindningen i de olika spåren. Genom att den enligt uppfinningen använda kabeln är relativt lättböjlig låter sig lindningen åstadkommas genom en förhållandevis enkel trädningsoperation, i vilken den böjliga kabeln träds in i de öppningar 52 som finns i spåren 50.

I figur 8 visas förenklat och principiellt den elektriska fältfördelningen kring en lindning hos en konventionell krafttransformator/reaktor, där 57 är en lindning och 58 en kärna och 59 anger ekvipotentiallinjer, dvs linjer där det elektriska fältet har samma storlek. Lindningens nedre del förutsättes befinna sig på jordpotential.

Potentialfördelningen bestämmer isolationssystemets uppbyggnad eftersom man måste ha tillräcklig isolation både mellan intilliggande varv hos lindningen och mellan varje varv och jord. Av figuren framgår således att den övre av lindningen utsättes för de högsta isolationstekniska belastningarna. En lindnings utformning och placering relativt kärnan bestäms på detta sätt huvudsakligen av den elektriska fältfördelningen i kärnfönstret.

Den kabel som kan komma till användning i de lindningar som ingår i torra krafttransformatorer/reaktorer enligt uppfinningen har beskrivits med ledning av fig 1. Kabeln kan, som omtalat tidigare, vara försedd med andra för speciella ändamål avsedda ytterligare yttre skikt, exempelvis för att förhindra för höga elektriska påkänningar på övriga områden av transformatorn/reaktorn. Ur

ALTERNATIVA KABELUTFORMNINGAR

I den i fig 10 illustrerade kabelvarianten nyttjas lika hänvisningsbeteckningar som tidigare blott med tillfogande av den utförandekaraktäristiska bokstaven a. I detta utförande omfattar kabeln flera elektriska ledare 42a, som är inbördes åtskilda med hjälp av isoleringen 44a. Uttryckt i andra ordalag tjänstgör isoleringen 44a både för isolation mellan individuella angränsande elektriska ledare 42 och mellan dessa och omgivningen. De olika elektriska ledarna 42a kan förläggas på olika sätt, något som föranleder varierande tvärsnittsform hos kabeln i dess helhet. I exemplet enligt fig 10 illustreras hurusom ledarna 42a är förlagda på en rät linje, något som föranleder en relativt flat tvärsnittsform hos kabeln. Av detta kan slutsatsen dras att kabelns tvärsnittsform kan variera inom vida gränser.

I fig 10 tänkes mellan angränsande elektriska ledare föreligga en spänning som är mindre än fasspänning. Närmare bestämt tänkes de elektriska ledarna 42a i fig 10 vara bildade av olika varv i själva lindningen, något som innebär att spänningen mellan dessa angränsande ledare är förhållandevis måttlig.

Såsom tidigare föreligger ett halvledande yttre skikt 45a utanför den av ett fast isoleringsmaterial åstadkomna isoleringen 44a. Ett inre skikt 43a av ett halvledande material är anordnat kring envar av nämnda elektriska ledare 42a, dvs att var och en av dessa uppvisar ett eget omgivande inre halvledande skikt 43a. Detta skikt 43a kommer således att fungera potentialutjämnande vad beträffar den individuella elektriska ledaren.

Varianten i fig 11 nyttjar lika hänvisningsbeteckningar som tidigare blott med tillägg av den utförandespecifika bokstaven b. Även här föreligger flera, närmare bestämt 3, elektriska ledare 42b. Mellan dessa tänkes i exemplet fasspänning föreligga, dvs en väsentligt högre spänning än den som föreligger mellan ledare 42a i utförandet enligt fig 10. I fig 11 föreligger ett inre halvledande skikt 43b, innanför vilket de elektriska ledarna 42b är anordnade. Var och en av de elektriska ledarna 42b är emellertid omsluten av ett eget ytterligare skikt 70 med egenskaper som motsvarar det inre skiktets

Patentkrav

1. Elektromagnetisk anordning innefattande åtminstone en magnetkrets (1) och åtminstone en elektrisk krets (2,3) innefattande åtminstone en lindning (4,5), varvid de magnetiska och elektriska kretsarna är induktivt kopplade till varandra och varvid anordningen innefattar en reglerinrättning (7) för att reglera funktionen hos anordningen, ***kännetecknad*** därav, att reglerinrättningen (7) är anordnad att reglera frekvens, amplitud och/eller fas vad avser elektrisk effekt till/från anordningen genom att reglerinrättningen innefattar organ (9) för reglering av det magnetiska flödet i magnetkretsen, och att den åtminstone ena lindningen (4,5) eller åtminstone en del därav innefattar minst en elektrisk ledare (42) med ett isolationssystem innefattande en elektrisk isolering (44) bildad av ett fast isoleringsmaterial och innanför detta ett inre skikt (43), att den åtminstone ena elektriska ledaren (42) är anordnad innanför det inre skiktet (43) och att det inre skiktet har en elektrisk konduktivitet som är lägre än den elektriska ledarens konduktivitet men tillräcklig för att bringa det inre skiktet (43) att fungera utjämnande vad avser det elektriska fältet utanför det inre skiktet.

2. Anordning enligt krav 1, ***kännetecknad*** därav, att reglerorganet innefattar minst en till magnetkretsen induktivt kopplad reglerlindning (9).

3. Anordning enligt krav 1 eller 2, ***kännetecknad*** därav, att reglerinrättningen (7) är anordnad att reglera reluktansen i magnetkretsen.

4. Anordning enligt något föregående krav, ***kännetecknad*** därav, att reglerinrättningen är anordnad att till det magnetiska flödet i magnetkretsen addera ett magnetiskt tillskottsflöde.

5. Anordning enligt krav 3, ***kännetecknad*** därav, att i magnetkretsen ingår material med en permeabilitet större än 1 och att reglerinrättningen (7) är anordnad att reglera reluktansen i magnetkretsen genom att variera permeabiliteten hos en eller flera sådana zoner av magnetkretsen som har variabel permeabilitet.

6. Anordning enligt krav 5, ***kännetecknad*** därav, att zonen eller zonerna med variabel permeabilitet innefattar ett eller flera gap i magnetkretsen.

7. Anordning enligt något föregående krav, ***kännetecknad*** därav, att magnetkretsen saknar magnetisk kärna.

8. Anordning enligt något av kraven 1-6, ***kännetecknad*** därav, att lindningen är lindad kring en magnetkärna (6).

9. Anordning enligt krav 2 och ett eller flera av resterande krav, ***kännetecknad*** därav, att reglerlindningen (9) och den elektriska kretsens lindning (4,5) är anordnad att genomflytas av väsentligen samma magnetiska flöde.

10. Anordning enligt något föregående krav, ***kännetecknad*** därav, att anordningen bildar en reaktor anordnad att medelst den åtminstone ena reglerlindningen reglera frekvens, amplitud och/eller fas avseende den elektriska effekt som flyter i den elektriska kretsens lindning (4,5).

11. Anordning enligt något av kraven 1-8 eller 10, ***kännetecknad*** därav, att den elektriska kretsen (2) uppvisar minst två seriekopplade lindningar (23, 24), att magnetkretsen innefattar åtminstone två alternativa flödesbanor (18,19), att den åtminstone ena reglerlindningen är anordnad att styra det magnetiska flödet att passera i någon av eller båda dessa flödesbanor och att den elektriska kretsens båda lindningar är så placerade att den ena av dem medelst sagda åtminstone ena reglerlindning är möjlig att koppla bort från magnetiskt flöde.

12. Anordning enligt något av kraven 1-9 eller 11, ***kännetecknad*** därav, att magnetkretsen är anordnad i statorn eller rotorn till en roterande elektrisk maskin.

13. Anordning enligt något av kraven 1-9, ***kännetecknad*** därav, att magnetkretsen (1) hör till en transformator med primär- och sekundärlindningar (4,5) och att primär- och sekundärlindningarna

samt reglerlindningen (9) är anordnade att genomflytas av samma magnetiska flöde.

14. Anordning enligt något av kraven 1-8 vid en transformator, ***kännetecknad*** därav, att transformatorns sekundärlindning innefattar åtminstone två seriekopplade lindningsdelar, att magnetkretsen innefattar åtminstone två alternativa flödesbanor (18,19), att åtminstone två förekommande reglerlindningar (9b1,9b2,9c1,9c2) är anordnade att styra det magnetiska flödet att passera i någon av eller båda dessa flödesbanor och att sekundärlindningens båda lindningsdelar är så placerade att den ena av dem medelst reglerlindningarna är möjlig att koppla bort från magnetiskt flöde.

15. Anordning enligt något av kraven 11 och 14, ***kännetecknad*** därav, att den uppvisar en magnetkärna med åtminstone tre parallellkopplade ben och att två av dessa hör till olika flödesbanor medan det tredje är gemensamt för de två flödesbanorna.

16. Anordning enligt något föregående krav. ***kännetecknad*** därav, att isolationssystemet utanför isolationen innefattar ett yttre skikt (45), som har en elektrisk konduktivitet som är högre än den hos isolationen för att det yttre skiktet genom anslutning till jord eller eljest relativt låg potential skall förmå att fungera potentialutjämnande.

17. Anordning enligt något föregående krav , ***kännetecknad*** av att det yttre skiktet är anordnat att i huvudsak innehålla det på grund av nämnda elektriska ledare (42) uppstående elektriska fältet innanför det yttre skiktet (45).

18. Anordning enligt något av föregående krav, ***kännetecknad*** därav, att det inre skiktet (43,) och den fasta isoleringen uppvisar väsentligen lika termiska egenskaper.

19. Anordning enligt något föregående krav, ***kännetecknad därav.*** att det yttre skiktet (45) och den fasta isoleringen uppvisar väsentligen lika termiska egenskaper.

20. Anordning enligt något av föregående krav, ***kännetecknad*** därav, att nämnda åtminstone ena ledare (42) utgör minst ett induktionsvarv.

21. Anordning enligt något av föregående krav, ***kännetecknad*** därav, att det inre och/eller yttre skiktet (43, 45) innefattar ett halvledande material.

22. Anordning enligt något föregående krav, ***kännetecknad*** därav, att det inre skiktet (43) och/eller det yttre skiktet (45) har en resistivitet inom området 10^{-6} Ωcm - 100 kΩcm, lämpligen 10^{-3}-1000 Ωcm, företrädesvis 1-500 Ωcm.

23. Anordning enligt något föregående krav , ***kännetecknad*** därav, att det inre skiktet (43) och/eller det yttre skiktet (45) har en resistans som per meter ledare/isolationssystem ligger inom området 50 μΩ - 5 MΩ.

24. Anordning enligt något föregående krav , ***kännetecknad*** därav, att den fasta isoleringen (44) och det inre skiktet (43) och/eller det yttre skiktet (45) utgörs av polymera material.

25. Anordning enligt något föregående krav, ***kännetecknad*** därav, att det inre skiktet (43) och/eller det yttre skiktet (45) och den fasta isoleringen (44) är fast förbundna med varandra över väsentligen hela gränsytan för att säkerställa vidhäftning även vid böjning och temperaturförändring.

26. Anordning enligt något föregående krav ***kännetecknad*** därav, att den fasta isolationen och det inre skiktet och/eller det yttre skiktet är av material med hög elasticitet för att bibehålla den inbördes vidhäftningen vid påfrestningar under drift.

27. Anordning enligt något föregående krav , ***kännetecknad*** därav, att den fasta isolationen och det inre skiktet och/eller det yttre skiktet är av material med väsentligen lika E-modul.

28. Anordning enligt något föregående krav, ***kännetecknad*** därav, att det inre skiktet (43) och/eller det yttre skiktet (45) och den fasta

isoleringen (44) utgörs av material med väsentligen lika termiska utvidgningskoefficienter.

29. Anordning enligt något föregående krav, ***kännetecknad*** därav, att ledaren (42) och dess isolationssystem utgör en lindning bildad medelst en böjlig kabel (41).

30. Anordning enligt något föregående krav, ***kännetecknad*** därav, att det inre skiktet (43) är i elektrisk kontakt med den åtminstone ena elektriska ledaren (42).

31. Anordning enligt krav 30, ***kännetecknad*** därav, att nämnda åtminstone ena elektriska ledare (42) innefattar ett antal kardeler och att åtminstone en kardel hos den elektriska ledaren (42) är åtminstone delvis oisolerad och anordnad i elektrisk kontakt med det inre skiktet (43).

32. Anordning enligt något föregående krav, ***kännetecknad*** därav, att ledaren (42) och dess isolationssystem är utformade för hög spänning, lämpligen över 10 kV, särskilt över 36 kV och företrädesvis över 72,5 kV.

33. Anordning enligt krav 12, **kännetecknad därav,** att magnetkretsen innefattar en eller flera magnetiska kärnor (48) med spår (50) för lindningen (41).

34. Anordning enligt något av kraven 12 och 33-34, ***kännetecknad*** därav, att den utgörs av en generator, motor eller synkronkompensator.

35. Anordning enligt något av kraven 12 och 33-35, ***kännetecknad*** därav, att den är direktansluten till ett för hög spänning, lämpligen 36 kV och däröver, utformat elkraftnät utan mellanliggande transformator.

36. Anordning enligt något av kraven 1-11 och 13-32, ***kännetecknad*** därav, att den utgörs av en krafttransformator/reaktor.

SAMMANDRAG

En elektromagnetisk anordning innefattar åtminstone en magnetkrets (1) och åtminstone en elektrisk krets (2, 3) innefattande åtminstone en lindning (4, 5). De magnetiska och elektriska kretsarna är induktivt kopplade till varandra. Anordningen innefattar en reglerinrättning (7) för att reglera funktionen hos anordningen. Denna reglerinrättning är anordnad att reglera frekvens, amplitud och/eller fas vad avser elektrisk effekt till/från anordningen genom att reglerinrättningen innefattar organ (9) för reglering av det magnetiska flödet i magnetkretsen.

(Fig 1)

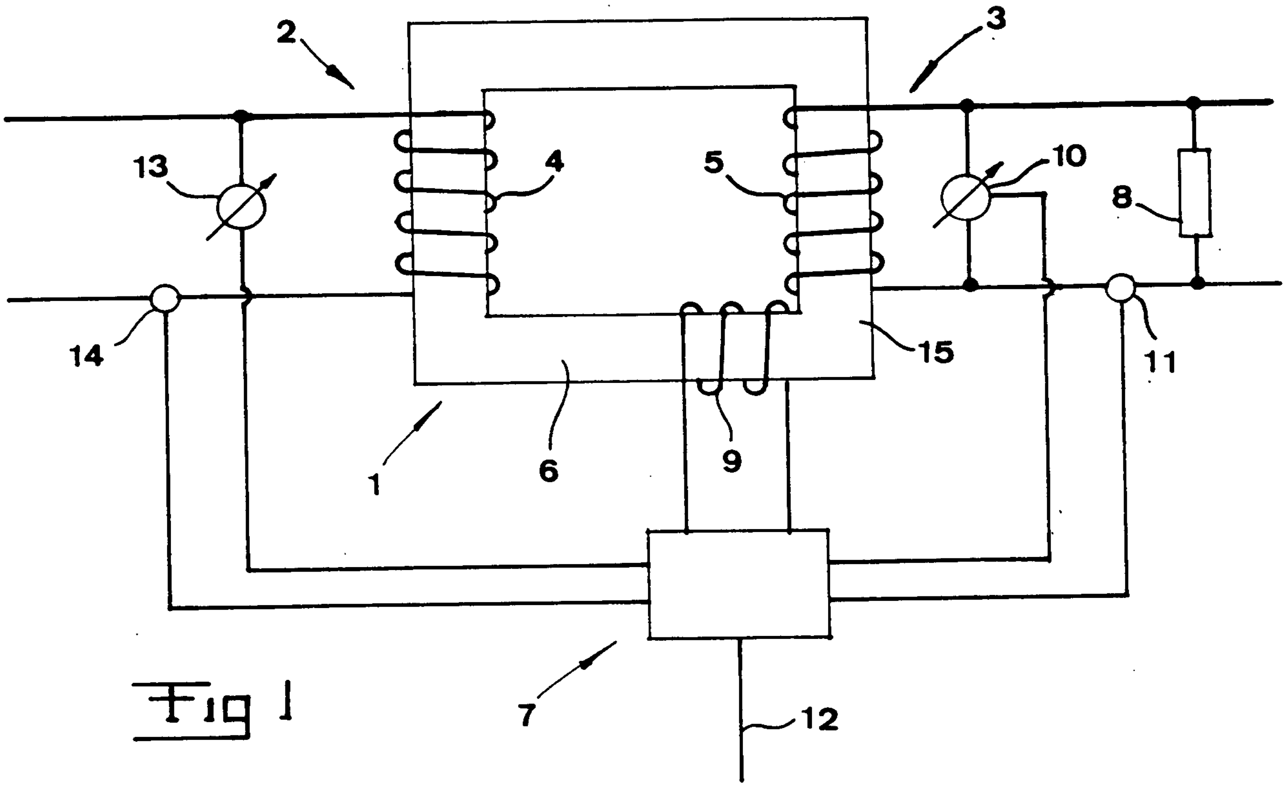

Fig 1

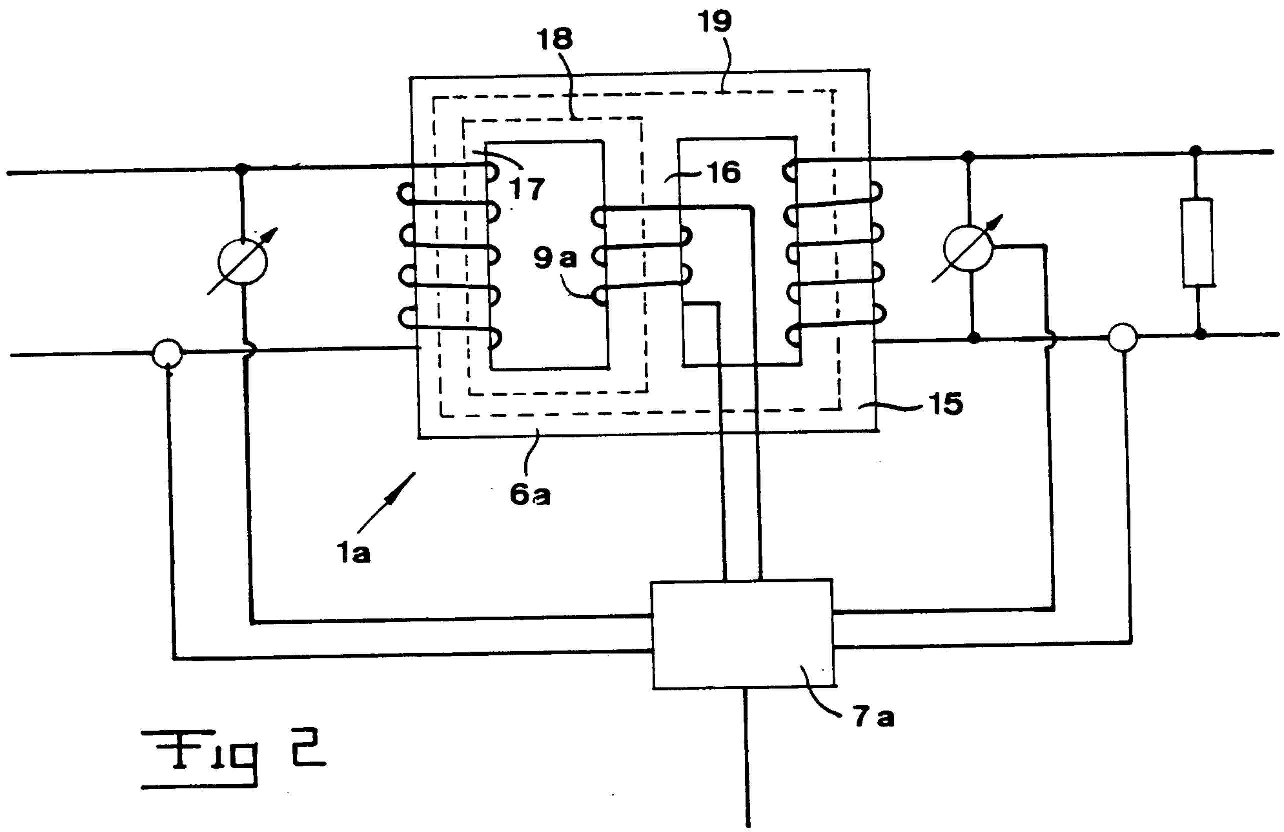

Fig 2

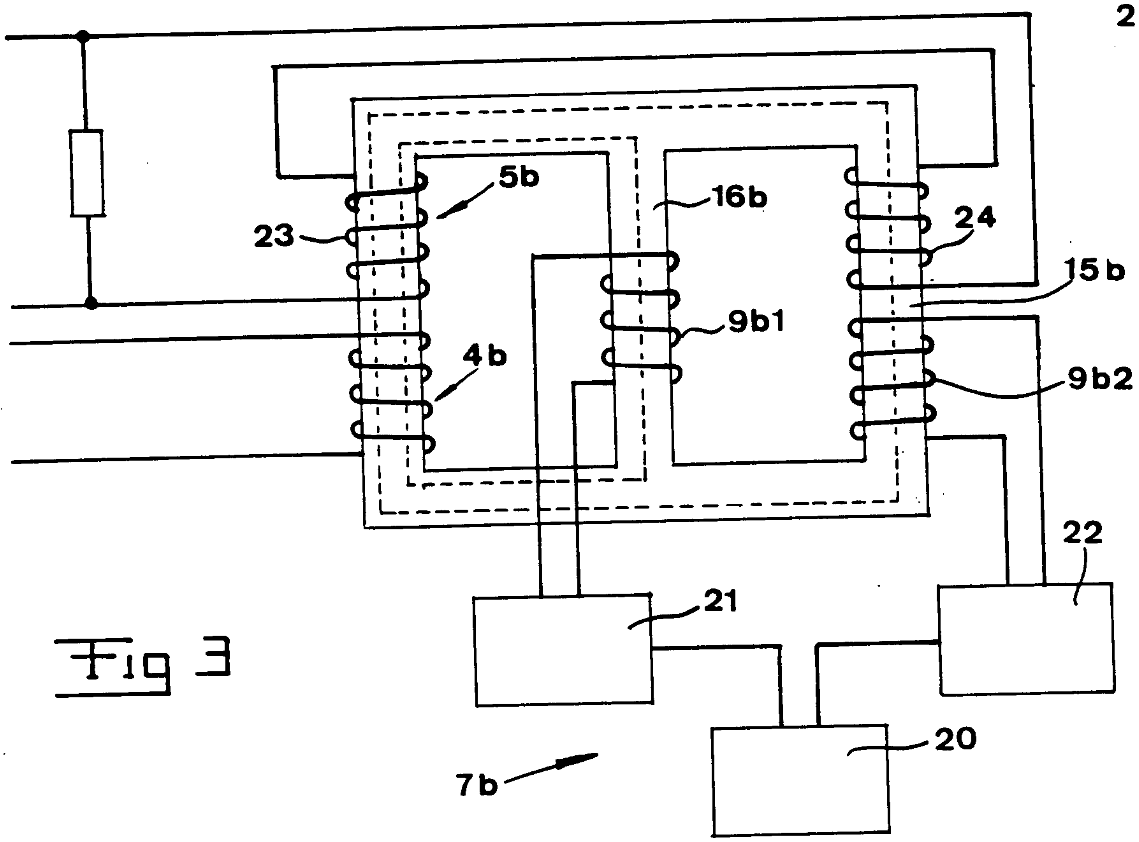
5b
23
16b
24
15b
9b1
4b
9b2
22
21
20
7b

Fig 3

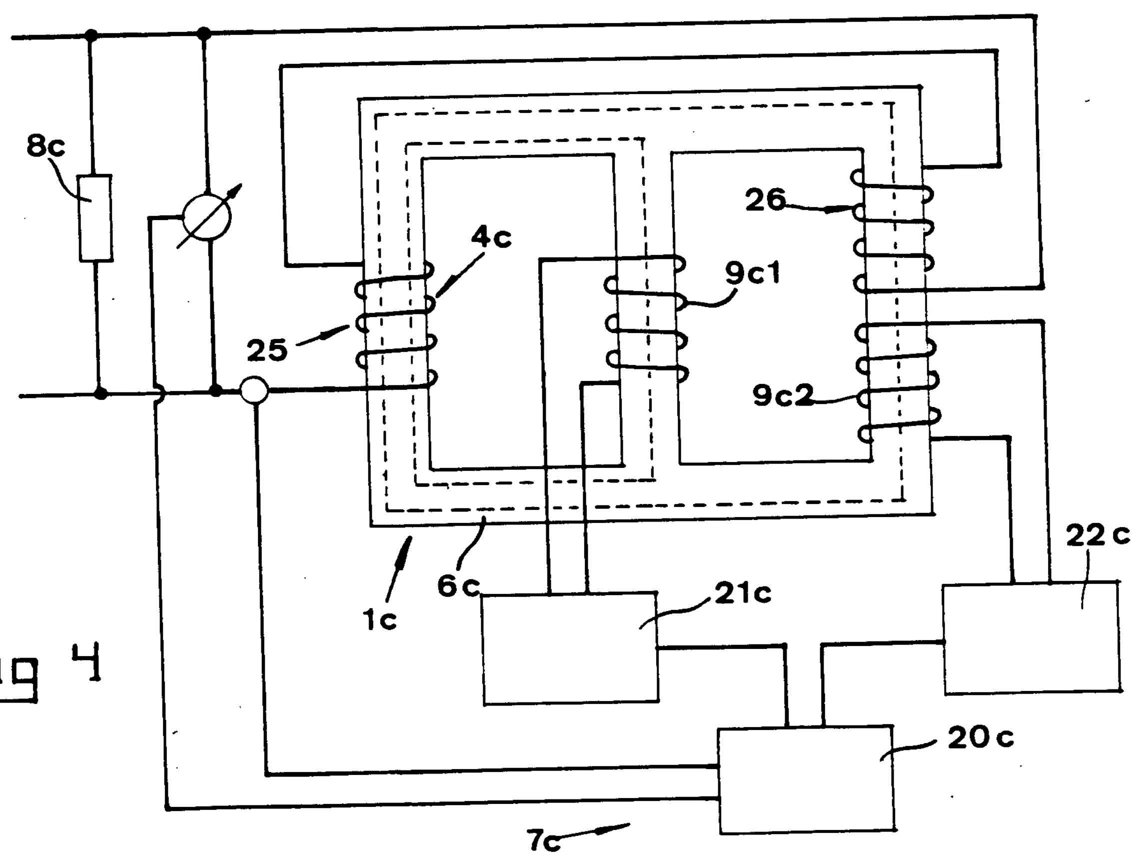
8c
26
4c
9c1
25
9c2
22c
6c
21c
1c
20c
7c

Fig 4

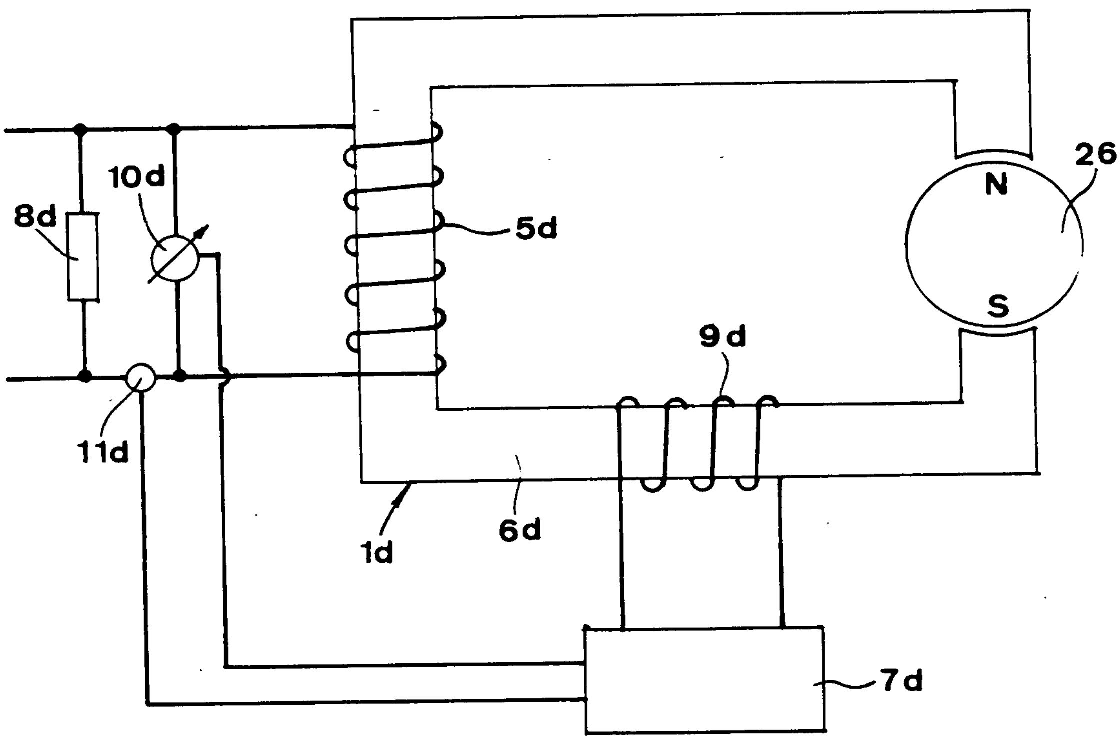

Fig 5

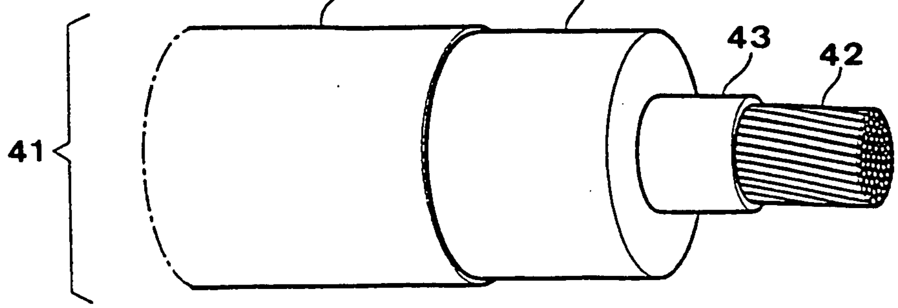

Fig 6

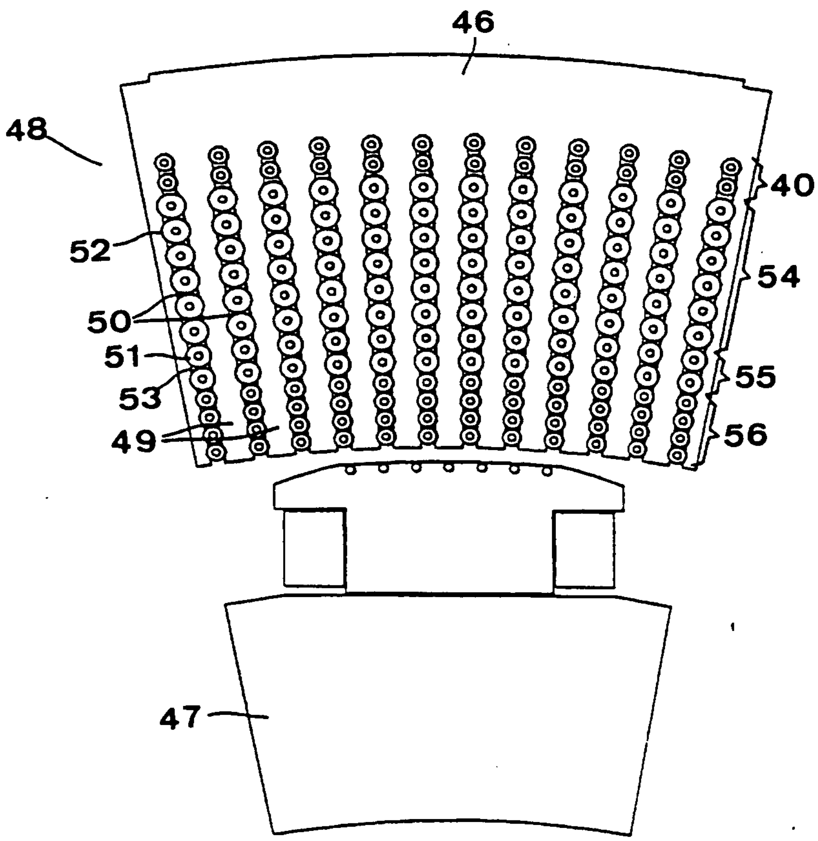

Fig 7

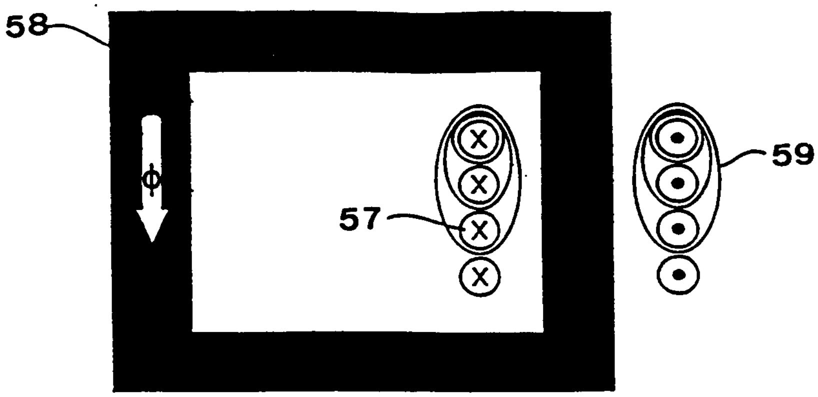

Fig 8

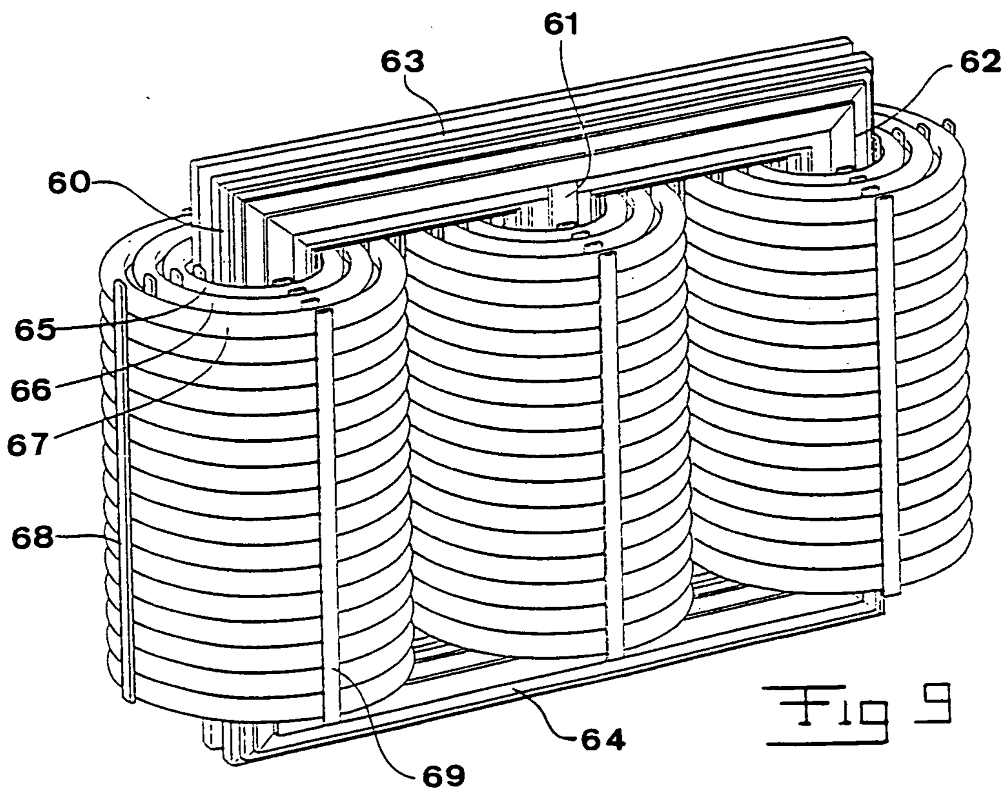

Fig 9

SUBSTITUTE SHEET

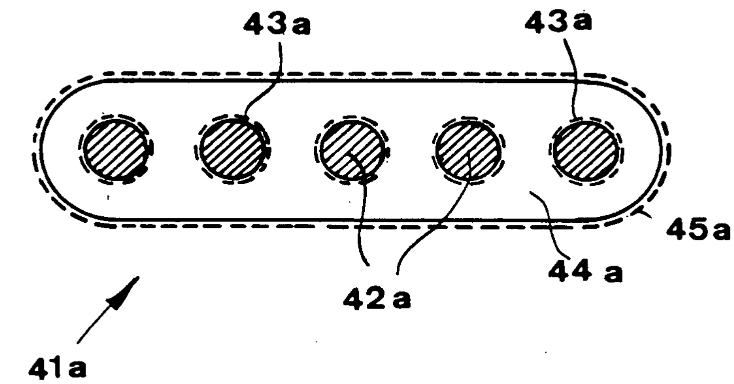

Fig 10

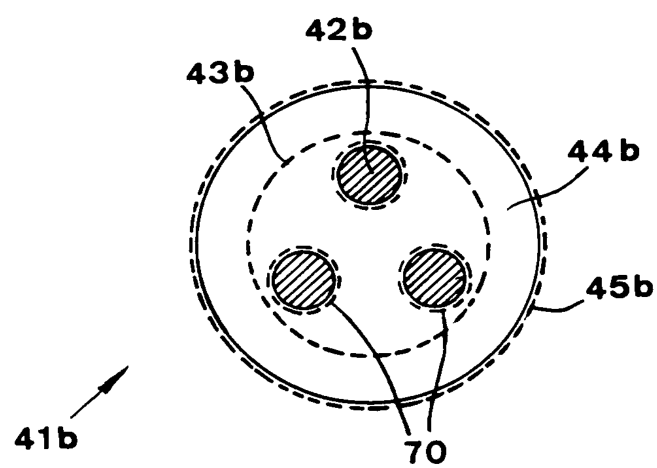

Fig 11

m.H

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PATENT COOPERATION TREATY

PCT

REC'D 16 MAR 2000

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference PCT 14818 HBN ijn	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/SE98/01733	International filing date *(day/month/year)* 29.09.1998	Priority date *(day/month/year)* 26.11.1997
International Patent Classification (IPC) or national classification and IPC7 H 01 F 27/32, H 02 K 3/30		
Applicant ABB AB ET AL		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of ______ sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
31.05.1999	07.03.2000
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17978 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Magnus Westöö/MN Telephone No. 08-782 25 00

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE98/01733

I. Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

☒ the international application as originally filed.

☐ the description, pages ______, as originally filed,
pages ______, filed with the demand,
pages ______, filed with the letter of ______,
pages ______, filed with the letter of ______.

☐ the claims, Nos. ______, as originally filed,
Nos. ______, as amended under Article 19,
Nos. ______, filed with the demand,
Nos. ______, filed with the letter of ______,
Nos. ______, filed with the letter of ______.

☐ the drawings, ~~sheets~~/fig ______, as originally filed,
~~sheets~~/fig ______, filed with the demand
~~sheets~~/fig ______, filed with the letter of ______,
~~sheets~~/fig ______, filed with the letter of ______.

2. The amendments have resulted in the cancellation of:

☐ the description, pages ______
☐ the claims, Nos. ______
☐ the drawings, ~~sheets~~/fig ______

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE98/01733

V. Resoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-36	YES
	Claims		NO
Inventive step (IS)	Claims	1-36	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-36	YES
	Claims		NO

2. Citations and explanations

Cited documents:
D1: US 5036165 A
D2: US 4109098 A

The invention relates to an electromagnetic device comprising at least one magnetic circuit, at least one electric circuit comprising at least one winding and a control arrangement. Said at least one winding or at least a part thereof comprises at least one electric conductor having an insulation system comprising an electric insulation formed by a solid insulation material and interiorly thereof an inner layer, that said at least one electric conductor is arranged interiorly of the inner layer and that the inner layer has an electrical conductivity which is lower than the conductivity of the electric conductor but sufficient to cause the inner layer to operate for equalization as concerns the electrical field exteriorly of the inner layer.

D1 discloses an electrical cable. A semiconducting layer equalizes the electrical potential on the exterior surface of an insulated conductor when the layer covers the surface. The layer prohibits the development of a corona discharge.

D2 discloses a high voltage cable. A conductor core is encompassed by a layer of semiconducting material. An insulation layer encompasses this semiconducting layer.

D1 and D2 show the state of the art technique, but do not anticipate the claimed invention. The invention is novel and is deemed to involve an inventive step. The industrial applicability of the invention is obvious.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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in its capacity as elected Office

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

Date of mailing (day/month/year) 19 July 1999 (19.07.99)	
International application No. PCT/SE98/01733	**Applicant's or agent's file reference** PCT 14205HB le
International filing date (day/month/year) 29 September 1998 (29.09.98)	**Priority date** (day/month/year) 26 November 1997 (26.11.97)
Applicant LEIJON, Mats	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

31 May 1999 (31.05.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

madc before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer F. Baechler Telephone No.: (41-22) 338.83.38

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International Bureau

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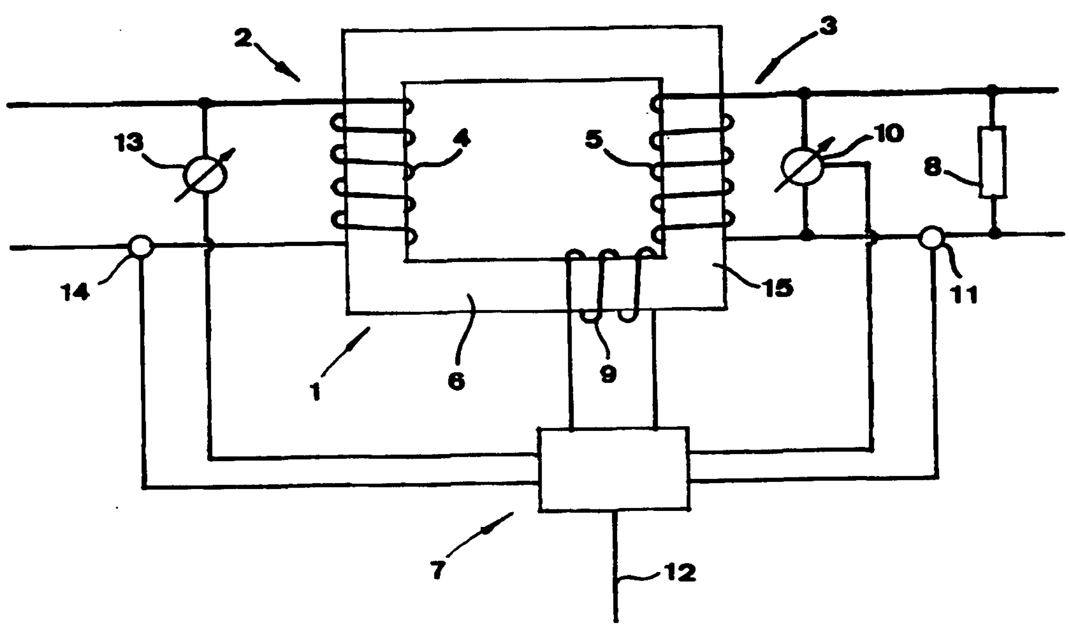

(57) Abstract

An electromagnetic device comprises at least one magnetic circuit (1) and at least one electric circuit (2, 3) comprising at least one winding (4, 5). The magnetic and electric circuits are inductively coupled to each other. The device comprises a control arrangement (7) to control operation of the device. This control arrangement is adapted to control frequency, amplitude and/or phase as concerns electric power to/from the device by the control arrangement comprising means (9) controlling the magnetic flux in the magnetic circuit.

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Electromagnetic device

FIELD OF THE INVENTION AND PRIOR ART

This invention is related to an electromagnetic device comprising at least one magnetic circuit and at least one electric circuit comprising at least one winding, the magnetic and electric circuits being inductively connected to each other and the device comprising a control arrangement to control operation of the device.

This electromagnetic device may be used in any electrotechnical connection. The power range may be from VA up to the 1000-MVA range. High voltage applications are primarily intended, up to the highest transmission voltages used today.

According to a first aspect of the invention a rotating electric machine is contemplated. Such electric machines comprise synchronous machines which are mainly used as generators for connection to distribution and transmission networks, commonly referred to below as power networks. The synchronous machines are also used as motors and for phase compensation and voltage control, in that case as mechanically idling machines. The technical field also comprises double-fed machines, asynchronous converter cascades, external pole machines, synchronous flux machines and asynchronous machines.

According to another aspect of the invention, said electromagnetic device is formed by a power transformer or reactor. For all transmission and distribution of electric energy, transformers are used and their task is to allow exchange of electric energy be-

tween two or more electric systems and for this, electromagnetic induction is utilized in a well-known manner. The transformers primarily intended with the present invention belong to the so-called power transformers with a rated power of from a few hundred kVA up to more than 1000 MVA with a rated voltage of from 3-4 kV and up to very high transmission voltages, 400 kV to 800 kV or higher.

Although the following description of the prior art with respect to the second aspect mainly refers to power transformers, the present invention is also applicable to reactors, both single-phase and three-phase reactors. As regards insulation and cooling there are, in principle, the same embodiments as for transformers. Thus, air-insulated and oil-insulated, self-cooled, pressure-oil cooled, etc., reactors are available. Although reactors have one winding (per phase) and may be designed both with and without a magnetic core, the description of the background art is to a large extent relevant also to reactors.

The at least one winding of the electric circuit may in some embodiments be air-wound but comprises as a rule a magnetic core of laminated, normal or oriented, sheet or other, for example amorphous or powder-based, material, or any other action for the purpose of allowing an alternating flux, and a winding. The circuit often comprises some kind of cooling system etc. In the case of a rotating electric machine, the winding may be disposed in the stator or the rotor of the machine, or in both.

A problem with known embodiments of electromagnetical devices of the above indicated nature is that it is either relatively difficult to achieve efficient control within a certain spectrum of parameters or that the control arrangements tend to be relatively costly. It is in this connection pointed out that it is known within the generator art to execute control of operation parameters via the field winding. If the rotor comprises electro-

magnets, this field winding is provided on the rotor with the disadvantages this involves in the form of a more expensive and more difficult-to-control embodiment. In the case of a permanent magnet rotor, the problem arises that field control is not practically possible. This makes it, of course, more difficult to carry out control in general and in especially delicate control situations in particular. A further problem with prior art is that the conventional winding technique makes it expensive to obtain the windings. The known embodiments also cause substantial energy losses and involve restrictions as far as the location of the windings in the magnetic circuit is concerned.

SUMMARY OF THE INVENTION

The object of the present invention is to devise ways to simplify and improve the possibilities to control operation of electromagnetic devices according to the precharacterizing part of the enclosed claim 1, better conditions for rational winding production and mounting also being aimed at.

The basic object of the present invention is achieved by arranging the control arrangement to control frequency, amplitude and/or phase with respect to electric power to/from the device by the control arrangement comprising means to control the magnetic flux in the magnetic circuit.

Thus, the present invention is based upon the idea to directly affect, by flux control, the magnetic flux in the magnetic circuit in a desired regard so as to be able to control the operation of the device. This provides a very rational and cost efficient embodiment, and besides increased possibilities to control so as to achieve an optimized operation.

According to a particularly preferred embodiment of the invention, the control means comprises at least one control winding

inductively connected to the magnetic circuit. The control arrangement is, accordingly, capable of effecting, via the control winding, required control of the magnetic flux in the magnetic circuit by applying, via the control winding, such control parameters that the magnetic flux in the magnetic circuit is affected in the required extent. The control winding could even be short-circuited. The magnetic flux may then in certain embodiments not pass the control winding. Depending upon the design of the magnetic circuit, partial or total blocking of the magnetic flux may occur.

Examples of control functions which may be achieved with the solution according to the invention are voltage change and voltage stabilization, elimination of transients, damping of oscillations in the power network, filtering-off of overtones, frequency adjustments and phase adjustments (in case separate control for the phases is provided for). It is pointed out that the control arrangement according to the invention may be adapted to add a magnetic flux addition to the magnetic flux in the magnetic circuit, i.e. the control arrangement could operate with direct energy supply.

The control according to the invention of the magnetic flux in the magnetic circuit means, for instance in a transformer, that a good control can be executed over the secondary winding voltage so that it fulfils the requirements imposed despite troublesome fluctuations regarding the primary voltage or the load connected to the secondary winding.

Further details and advantages with the flux control according to the invention in the magnetic circuit will appear from the following detailed description.

It is within the scope of the invention that at least one of the windings of the electromagnetic device or at least a part of this

winding comprises at least one flexible electrical conductor having a casing, which is magnetically permeable but capable of substantially enclosing the electric field occurring around the conductor. Expressed in other words, this means that the flexible electrical conductor and the casing thereof (in the form of an insulation system) are formed by means of a flexible cable. This involves substantial advantages with respect to manufacturing and mounting compared to the rigid windings in prefabricated shape which have been conventional up to now. The insulation system according to the invention results, in addition, in absence of gaseous and liquid insulation materials.

Since the electric field occurring about the electric conductor in the cable in the invention is substantially enclosed in the insulation system, the invention reduces occurring losses such that the device accordingly may operate with a higher degree of efficiency. The reduction of losses results, in its turn, in a lower temperature in the device, which reduces the need for cooling and allows possibly occurring cooling devices to be designed in a more simple way than without this aspect of the invention.

As to the aspect of the invention as a rotating electric machine it is thus possible to operate the machine with such a high voltage that the conventional step-up transformers can be omitted. That is, the machine can be operated with a considerably higher voltage than machines according to the state of the art to be able to perform direct connection to power networks. This means considerably lower investment costs for systems with a rotating electric machine and the total efficiency of the system can be increased. The invention eliminates the need for particular field control measures at certain areas of the winding, such field control measures having been necessary according to the prior art. A further advantage is that the invention makes it more simple to obtain under- and overmagnetization for the purpose of reducing

reactive effects as a result of voltage and current being out of phase with each other.

As to the aspect of the invention as a power transformer/ reactor, the invention, first of all, eliminates the need for oil filling of the power transformers and the problems and disadvantages associated thereto.

The design of the winding so that it comprises, along at least a part of its length, an insulation formed by a solid insulating material, inwardly of this insulation an inner layer and outwardly of the insulation an outer layer with these layers made of a semi conducting material makes it possible to enclose the electric field in the entire device within the winding. The term "solid insulating material" used herein means that the winding is to lack liquid or gaseous insulation, for instance in the form of oil. Instead the insulation is intended to be formed by a polymeric material. Also the inner and outer layers are formed by a polymeric material, though a semiconducting such.

The inner layer and the solid insulation are rigidly connected to each other over substantially the entire interface. Also the outer layer and the solid insulation are rigidly connected to each other over substantially the entire interface therebetween. The inner layer operates equalizing with respect to potential and, accordingly, equalizing with respect to the electrical field outwardly of the inner layer as a consequence of the semiconducting properties thereof. The outer layer is also intended to be made of a semiconducting material and it has at least an electrical conductivity being higher than that of the insulation so as to cause the outer layer, by connection to earth or otherwise a relatively low potential, to function equalizing with regard to potential and to substantially enclose the electrical field resulting due to said electrical conductor inwardly of the outer layer. On the other

hand, the outer layer should have a resistivity which is sufficient to minimize electrical losses in said outer layer.

The rigid interconnection between the insulating material and the inner and outer semiconducting layers should be uniform over substantially the entire interface such that no cavities, pores or similar occur. With the high voltage levels contemplated according to the invention, the electrical and thermal loads which may arise will impose extreme demands on the insulation material. It is known that so-called partial discharges, PD, generally constitute a serious problem for the insulating material in high-voltage installations. If cavities, pores or the like arise, internal corona discharges may arise at high electric voltages, whereby the insulating material is gradually degraded and the result could be electric breakdown through the insulation. This may lead to serious breakdown of the electromagnetic device. Thus, the insulation should be homogenous.

The inner layer inwardly of the insulation should have an electrical conductivity which is lower than that of the electrical conductor but sufficient for the inner layer to function equalizing with regard to potential and, accordingly, equalizing with respect to the electrical field externally of the inner layer. This in combination with the rigid interconnection of the inner layer and the electrical insulation over substantially the entire interface, i.e. the absence of cavities etc, means a substantially uniform electrical field externally of the inner layer and a minimum of risk for PD.

It is preferred that the inner layer and the solid electrical insulation are formed by materials having substantially equal thermal coefficients of expansion. The same is preferred as far as the outer layer and the solid insulation are concerned. This means that the inner and outer layers and the solid electrical insulation will form an insulation system which on temperature changes

expands and contracts uniformly as a monolithic part without those temperature changes giving rise to any destruction or disintegration in the interfaces. Thus, intimacy in the contact surface between the inner and outer layers and the solid insulation is ensured and conditions are created to maintain this intimacy during prolonged operation periods. The adherence should be of such a nature that adherence between at least the inner layer and the solid insulation and preferably also the outer layer and the solid insulation is ensured also in connection with such bending that the electric conductor and the insulation system will be subjected to. It is pointed out here that the cable, in order to be able to carry out threading of the winding, should be bendable or flexible in a radius of curvature which is less than 25 times the cable diameter, preferably less than 15 times the cable diameter. The most preferred is that the cable is flexible down to a radius of curvature which is less than or substantially similar to 8 times the cable diameter.

It is essential that the insulation system consists of materials having a good elasticity. The E-modulus of the materials should be comparatively low, i.e. the resistance to deformation of the material should be relatively low. In order to avoid that hazardous shear tensions occur in the border zone between different layers contained in the insulation system, it is preferred that the electricity (E-modulus) of the layers contained in the insulation system is substantially equal.

The electrical load on the insulation system decreases as a consequence of the fact that the inner and the outer layers of semiconducting material around the insulation will tend to form substantially equipotential surfaces and in this way the electrical field in the insulation properly will be distributed relatively uniformly over the thickness of the insulation.

It is known, per se, in connection with transmission cables for high-voltage and for transmission of electric energy, to design conductors with an insulation of a solid insulation material with inner and outer layers of semiconducting material. In transmission of electric energy, it has since long been realised that the insulation should be free from defects. However, in high voltage cables for transmission, the electric potential does not change along the length of the cable but the potential is basically at the same level. However, also in high voltage cables for transmission purposes, instantaneous potential differences may occur due to transient occurrences, such as lightning. According to the present invention a flexible cable according to the enclosed claims is used as a winding in the electromagnetic device.

An additional improvement may be achieved by constructing the electric conductor in the winding from smaller, so-called strands, at least some of which are insulated from each other. By making these strands to have a relatively small cross section, preferably approximately circular, the magnetic field across the strands will exhibit a constant geometry in relation to the field and the occurrence of eddy currents are minimized.

According to the invention, the winding is thus preferably made in the form of a cable comprising the electric conductor and the previously described insulation system, the inner layer of which extends about the strands of the conductor. Outside of this inner semiconducting layer is the main insulation of the cable in the form of a solid insulation material.

The outer semiconducting layer shall according to the invention exhibit such electrical properties that a potential equalization along the conductor is ensured. The outer layer may, however, not exhibit such conductivity properties that an induced current will flow along the surface, which could cause losses which in turn may create an unwanted thermal load. For the inner and

outer layers the resistance statements (at 20°C) defined in the enclosed claims 22 and 23 are valid. With respect to the inner semiconducting layer, it must have a sufficient electrical conductivity to ensure potential equalization for the electrical field but at the same time this layer must have such a resistivity that the enclosing of the electric field is ensured.

It is important that the inner layer equalizes irregularities in the surface of the conductor and forms an equipotential surface with a high surface finish at the interface with the solid insulation. The inner layer may be formed with a varying thickness but to ensure an even surface with respect to the conductor and the solid insulation, the thickness is suitably between 0.5 and 1 mm.

Such a flexible winding cable which is used according to the invention in the electromagnetic device thereof is an improvement of a XLPE (cross-linked poly ethylene) cable or a cable with EP (ethylene-propylene) rubber insulation. The improvement comprises, inter alia, a new design both as regards the strands of the conductor and in that the cable, at least in some embodiments, has no outer casing for mechanical protection of the cable. However, it is possible according to the invention to arrange a conducting metal shield and an outer mantle externally of the outer semiconducting layer. The metal shield will then have the character of an outer mechanical and electrical protection, for instance to lightning. It is preferred that the inner semiconducting layer will lie on the potential of the electrical conductor. For this purpose at least one of the strands of the electrical conductor will be uninsulated and arranged so that a good electrical contact is obtained to the inner semiconducting layer. Alternatively, different strands may be alternatingly brought into electrical contact with the inner semiconducting layer.

Manufacturing transformer or reactor windings of a cable according to the above entails drastic differences as regards the electric field distribution between conventional power transformers/reactors and a power transformer/reactor according to the invention. The decisive advantage with a cable-formed winding according to the invention is that the electric field is enclosed in the winding and that there is thus no electric field outside the outer semiconducting layer. The electric field achieved by the current-carrying conductor occurs only in the solid main insulation. Both from the design point of view and the manufacturing point of view this means considerable advantages:

- the windings of the transformer may be formed without having to consider any electric field distribution and the transposition of strands, mentioned under the background art, is omitted;

- the core design of the transformer may be formed without having to consider any electric field distribution;

- no oil is needed for electrical insulation of the winding, that is, the medium surrounding the winding may be air;

- no special connections are required for electrical connection between the outer connections of the transformer and the immediately connected coils/windings, since the electrical connection, contrary to conventional plants, is integrated with the winding;

- the manufacturing and testing technology which is needed for a power transformer according to the invention is considerably simpler than for a conventional power transformer/reactor since the impregnation, drying and vacuum treatments described under the description of the background art are not needed.

In application of the invention as a rotating electric machine a substantially reduced thermal load on the stator is obtained.

Temporary overloads of the machine will, thus, be less critical and it will be possible to drive the machine at overload for a longer period of time without running the risk of damage arising. This means considerable advantages for owners of power generating plants who are forced today, in case of operational disturbances, to rapidly switch to other equipment in order to ensure the delivery requirements laid down by law.

With a rotating electric machine according to the invention, the maintenance costs can be significantly reduced because transformers and circuit breakers do not have to be included in the system for connecting the machine to the power network.

Above it has already been described that the outer semiconducting layer of the winding cable is intended to be connected to ground potential. The purpose is that the layer should be kept substantially on ground potential along the entire length of the winding cable. It is possible to divide the outer semiconducting layer by cutting the same into a number of parts distributed along the length of the winding cable, each individual layer part being connectable directly to ground potential. In this way a better uniformity along the length of the winding cable is achieved.

Above it has been mentioned that the solid insulation and the inner and outer layers may be achieved by, for instance, extrusion. Other techniques are, however, also well possible, for instance formation of these inner and outer layers and the insulation respectively by means of spraying of the material in question onto the conductor/winding.

It is preferred that the winding cable is designed with a circular cross section. However, also other cross sections may be used in cases where it is desired to achieve a better packing density.

To build up a voltage in the rotating electric machine, the cable is disposed in several consecutive turns in slots in the magnetic core. The winding can be designed as a multi-layer concentric cable winding to reduce the number of coil-end crossings. The cable may be made with tapered insulation to utilize the magnetic core in a better way, in which case the shape of the slots may be adapted to the tapered insulation of the winding.

A significant advantage with a rotating electric machine according to the invention is that the E field is near zero in the coil-end region outside the outer semiconductor and that with the outer casing at ground potential, the electric field need not be controlled. This means that no field concentrations can be obtained, neither within sheets, in coil-end regions nor in the transition therebetween.

In a method for manufacturing a device according to the invention, a flexible cable, which is threaded into openings in slots in a magnetic core of the rotating electrical machine, is used as a winding. Since the cable is flexible, it can be bent and this permits a cable length to be disposed in several turns in a coil. The coil ends will then consist of bending zones in the cables. The cable may also be joined in such a way that its properties remain constant over the cable length. This method entails considerable simplifications compared with the state of the art. The so-called Roebel bars are not flexible but must be preformed into the desired shape. Winding of insulation and impregnation of the coils is also an exceedingly complicated and expensive technique when manufacturing rotating electric machines today.

To sum up, thus, an electromagnetic device in the form of a rotating electric machine according to the invention means a considerable number of important advantages in relation to corresponding prior art machines. First of all, the machine according to the invention can be connected directly to a power

network at all types of high voltage. Another important advantage is that ground potential has been consistently conducted along at least a part of and preferably along the whole winding, which means that the coil-end region can be made compact and that bracing means at the coil-end region can be applied at practically ground potential. Still another important advantage is that oil-based insulation and cooling systems disappear also in rotating electric machines as already has been pointed out above with regard to power transformers/reactors. This means that no sealing problems may arise and that the dielectric ring previously mentioned is not needed. Important is also that all forced cooling can be made at ground potential.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the enclosed drawings, a more specific description of embodiment examples of the invention will follow hereinafter.

In the drawings:

Fig 1 is a diagrammatical view illustrating the device according to the invention in the form of a transformer;
Fig 2 is a diagrammatical view of a transformer variant;
Fig 3 is a diagrammatical view of a further transformer variant;
Fig 4 is a view of an embodiment similar to the one in Fig 3 but concerns a reactor;
Fig 5 is a diagrammatical view illustrating a generator embodiment;
Fig 6 is a partly cut view showing the parts included in the current modified standard cable;
Fig 7 is an axial end view of a sector/pole pitch of a magnetic circuit according to the invention;

Fig 8	is a view showing the electric field distribution around a winding of a conventional power transformer/reactor;
Fig 9	is a perspective view showing an embodiment of a power transformer according to the invention;
Fig 10	is a cross section illustrating a cable structure modified relative to Fig 1 and having several electrical conductors; and
Fig 11	is a cross section of a further cable structure comprising several electric conductors but in another arrangement than that in Fig 10.

DESCRIPTION OF PREFERRED EMBODIMENTS

The electromagnetic device illustrated in Fig 1 has the nature of a transformer. It comprises a magnetic circuit 1 and two electric circuits 2, 3, each comprising at least one coil shaped winding 4 and 5 respectively.

It is illustrated in the example that the transformer comprises a core 6 of a magnetic material. The core consists suitably of a package of magnetic sheets to reduce eddy-current losses. However, it is pointed out that it is not a prerequisite for application of the invention that a core is really present. Air wound embodiments etc are, thus, well possible within the scope of the invention. It follows from this that the term magnetic circuit is to be interpreted in a wide sense. The term in question means, accordingly, not more than that the magnetic field generated by the windings 4, 5 occurring should be capable of generating a magnetic flux.

The device according to the invention comprises an arrangement generally denoted 7 to control operation of the transformer. This control arrangement 7 is adapted to control frequency, amplitude and/or phase as concerns electric power exiting the transformer.

In the example the electric circuit 2 forms the primary side of the transformer whereas the electric circuit 3 forms the secondary side of the transformer. Power from the device exits, accordingly, via the secondary circuit 3, to which a load diagrammatically indicated with 8 is coupled. This load may be of an arbitrary nature, e.g. consumers proper but also distribution and transmission networks.

The control arrangement 7 comprises means 9 for controlling the magnetic flux in the magnetic circuit 1. The control means 9 includes, in the example, at least one control winding inductively connected to the magnetic circuit 1. In the example this control winding 9 is wound about a portion of the core 6. In a coreless transformer embodiment the control winding 9 must be co-ordinated such with the primary and secondary windings 4 and 5 respectively that the magnetic flux induced in the coreless magnetic circuit is inductively coupled to the control winding 9.

The control arrangement 7 is, according to a preferred embodiment of the invention, conceived to be of an active type, i.e. the control arrangement 7 should be adapted to actively control, via the control winding 9, the magnetic flux in the magnetic circuit 9 to obtain the desired character. It is then preferred that the control arrangement 7 comprises an external power source such that the control arrangement 7 is capable of controlling the magnetic flux through the magnetic circuit 1 by causing a current to flow through the winding 9. The invention is particularly preferable in connection with high voltage applications. This means, accordingly, that a comparatively high voltage is normally intended to be associated to the electric circuits 2 and 3. In such a case, it is, however, sufficient for control purposes that the control arrangement 7 causes a relatively high current to flow in the winding 9 with a relatively low voltage. The control arrangement 7 may be adapted to, for control purposes, add a magnetic flux addition to the magnetic flux in the magnetic circuit 1. This flux

addition will be added to the flux otherwise occurring and by suitable control of this flux addition, the desired parameters with regard to the power exiting through the secondary circuit 3 may be achieved. The arrangement 7 may be adapted to receive, as basis for its control function, voltage information from a voltage measuring device 10 with respect to the voltage in the secondary circuit and/or over the load 8. A current measuring member 11 serves for current measurement in the secondary circuit 3. The flux addition generated via the control arrangement 7 may, as mentioned before, be used to control frequency, amplitude and/or phase as concerns the power exiting via the secondary circuit 3.

It is pointed out that the control arrangement 7 may be adapted to obtain external control instructions via an input 12.

Furthermore, it is pointed out that the control arrangement 7 may be adapted to effect a passive control via the control winding 9. A passive control in this regard means that power from some external source is not used for control. In this connection it is pointed out that the control arrangement 7 may be capable of coupling one or more passive elements, such as resistors, capacitors or inductances coupled in series or parallel, over the control winding 9. Such passive elements coupled to the control winding 9 in a manner adapted to the purpose enable, accordingly, different influences on the magnetic flux, said influences in their turn resulting in consequences with respect to frequency, amplitude and/or phase as concerns the electric power from the device.

It also appears from Fig 1 that the device on its primary side comprises a voltage measuring device 13 and a current measuring device 14 similar to what is occurring on the secondary side.

Fig 2 illustrates a transformer embodiment differing from the one just described in Fig 1 only in the regard that the magnetic circuit 1 here comprises a core 6 comprising a further leg 16 in addition to the one occurring on the secondary side in Fig 1 and denoted 15 and the one occurring on the primary side and denoted 17. Thus, this means that the core 6 according to Fig 2 will form two different flux paths diagrammatically indicated with 18 and 19 respectively. The control winding 9a is arranged in this case around the central leg 16, i.e. at the flux path 18, which passes the primary winding 4 of the transformer. The second flux path 19, on the contrary, passes around the control winding 9a via the secondary winding 5. It is now possible via the control arrangement 7, to affect the magnetic flux in the leg 16 by means of the control winding 9a, which in its turn will affect the magnetic flux in the leg 15 through the winding 5 of the secondary side. Expressed in other words, the control winding 9a is here only associated to one of the two flux paths.

The variant in Fig 3 means addition of a further control winding 9b2 to the one already occurring 9b1. These two control windings are arranged around its own of the legs 16b, 15b, i.e. these control windings 9b1 and 9b2 will belong to its own of the flux paths 18, 19. The control arrangement 7b comprises a control unit 20, which in its turn controls control elements 21 and 22 respectively coordinated with the control windings 9b1 and 9b2 respectively. By actively or passively controlling the control elements 21, 22 via the control unit 20, an adjustment may be made so that the magnetic flux either passes through only one of the flux paths 18, 19 or is divided on the same.

In connection with Fig 3 it should also be mentioned that the secondary winding 4b of the transformer comprises at least two winding parts 23 and 24 respectively coupled in series. The magnetic flux in both flux paths 18, 19 passes through the main winding part 23 whereas only the flux in the flux path 19 passes

through the winding part 24. Thus, this means that when the magnetic flux is allowed to pass only through the leg 16b by means of the control windings 9b1 and 9b2, no magnetic flux passes through the winding part 24. Thus, this means lower output voltage than that which is due for the operation case where the magnetic flux passes entirely through the flux path 19 than when the total magnetic flux passes through both secondary winding parts 23 and 24. Thus, the control winding 9b1 is intended, in such an operation case, to have interrupted magnetic flux through the leg 16b entirely or at least partially.

Fig 4 illustrates a reactor embodiment somewhat reminding of the transformer according to Fig 3. The difference consists in that the reactor does not have any secondary side so that instead its power winding is divided into two winding parts 25, 26. As in the preceding embodiment, there are two control windings 9c1 and 9c2, by means of which the magnetic flux may be controlled so that it passes through the winding part 26 in a desired degree. The entire flux always passes through the winding part 25.

Fig 5 illustrates a very simplified generator embodiment, the rotor of which is denoted 26. This rotor is in the example conceived to be a permanent magnet rotor. It would, however, also be possible to design the rotor with field windings. The magnetic circuit 1d comprises here an electric output circuit 5d inductively coupled to the magnetic flux in the core 6d. The core 6d has portions located adjacent to the rotor 26 such that the permanent magnets will generate a magnetic flux in the core during rotation of the rotor. This flux passes through the output winding 5d and generates an output effect therein. The control arrangement 7d comprises as before a control winding 9d inductively coupled to the magnetic circuit 1d. Measuring devices 10d and 11d respectively for voltage and current occur also here to supervise the output power. By means of the control arrangement

7d the control winding 9d may now be subjected to a functionality, required for the control purpose, passively or actively, for imparting the output power from the generator desired properties with regard to frequency, amplitude and/or phase.

It is pointed out that very simplified embodiments are presented in the figures and this more specifically only with one phase. In reality the embodiments may be much more complicated, in particular multiphase embodiments. The number of windings and winding parts may be much higher than what has been discussed, not only as far as the primary and secondary windings are concerned but also with respect to the number of control windings. Also the magnetic circuits may have a varying design depending upon functional requirements.

It is particularly pointed out that the circumstance that according to the invention at least one of the occurring windings comprises an electric conductor surrounded by two mutually spaced equipotential layers and a solid insulation placed between these layers means that the electric field around the conductor will be substantially enclosed in the cable such that the primary and secondary windings may be placed anywhere on the magnetic circuit with a very great freedom. Even interposition of the windings is possible. It is in this connection pointed out that the control arrangement is useful for transformers both of the type with a core and a shell.

In particular in high voltage applications the just described design of the winding is suitable. It is pointed out that normally the control winding/control windings 9 will be at a lower potential than the power windings, for what reason the control winding/control windings do not necessarily have to be provided with such an insulation system as at least one of the power windings.

An important aspect for being able to provide an electromagnetic device in accordance with the invention, is to use for at least one of the winding a conductor cable with a solid electrical insulation with an inner semiconducting layer or casing between the insulation and one or more electrical conductors located inwardly thereof and with an outer semiconducting layer or casing located outwardly of the insulation. Such cables are available as standard cables for other power engineering fields of use, namely power transmission. To be able to describe an embodiment, initially a short description of a standard cable will be made. The inner current-carrying conductor comprises a number of strands. Around the strands there is a semiconducting inner layer or casing. Around this semiconducting inner layer, there is an insulating layer of solid insulation. The solid insulation is formed by a polymeric material with low electrical losses and a high breakthrough strength. As concrete examples polyethylene (PE) and then particularly cross-linked polyethylene (XLPE) and ethylene-propylene (EP) may be mentioned. Around the outer semiconducting layer a metal shield and an outer insulation casing may be provided. The semiconducting layers consist of a polymeric material, for example ethylene-copolymer, with an electrically conducting constituent, e. g. conductive soot or carbon black. Such a cable will be referred to hereunder as a power cable.

A preferred embodiment of a cable intended for a winding in a rotating electrical machine appears from Fig 6. The cable 41 is described in the figure as comprising a current-carrying conductor 42 which comprises transposed both non-insulated and insulated strands. Electromechanically transposed, solidly insulated strands are also possible. These strands may be stranded/transposed in a plurality of layers. Around the conductor there is an inner semiconducting layer 43 which, in turn, is surrounded by a homogenous layer of a solid insulation material. The insulation 44 is entirely without insulation material of liquid

or gaseous type. This layer 44 is surrounded by an outer semiconducting layer 45. The cable used as a winding in the preferred embodiment may be provided with metal shield and external sheath but must not be so. To avoid induced currents and losses associated therewith in the outer semiconducting layer 45, this is cut off, preferably in the coil end, that is, in the transitions from the sheet stack to the end windings. The cut-off is carried such that the outer semiconducting layer 45 will be divided into several parts distributed along the cable and being electrically entirely or partly separated from each other. Each cut-off part is then connected to ground, whereby the outer semiconducting layer 45 will be maintained at, or near, ground potential in the whole cable length. This means that, around the solidly insulated winding at the coil ends, the contactable surfaces, and the surfaces which are dirty after some time of use, only have negligible potentials to ground, and they also cause negligible electric fields.

To optimize a rotating electric machine, the design of the magnetic circuit as regards the slots and the teeth, respectively, are of decisive importance. As mentioned above, the slots should connect as closely as possible to the casing of the coil sides. It is also desirable that the teeth at each radial level are as wide as possible. This is important to minimize the losses, the magnetization requirement, etc., of the machine.

With access to a conductor for the winding such as for example, the cable described above, there are great possibilities of being able to optimize the magnetic core from several points of view. In the following, a magnetic circuit in the stator of the rotating electric machine is referred to. Figure 7 shows an embodiment of an axial end view of a sector/pole pitch 46 of a machine according to the invention. The rotor with the rotor pole is designated 47. In conventional manner, the stator is composed of a laminated core of electric sheets successively composed of

sector-shaped sheets. From a back portion 48 of the core, located at the radially outermost end, a number of teeth 49 extend radially inwards towards the rotor. Between the teeth there are a corresponding number of slots 50. The use of cables 51 according to the above among other things permits the depth of the slots for high-voltage machines to be made larger than what is possible according to the state of the art. The slots have a cross section tapering towards the rotor since the need of cable insulation becomes lower for each winding layer towards the rotor. As is clear from the figure, the slot substantially consists of a circular cross section 52 around each layer of the winding with narrower waist portions 53 between the layers. With some justification, such a slot cross section may be referred to as a "cycle chain slot". Since there will be required, in such a high voltage machine, a relatively large number of layers and the availability of cables in relevant dimensions and having relevant insulation and external semiconductors is restricted it may in practice be difficult to achieve a desired continuous tapering of the cable insulation and the stator slot respectively. In the embodiment shown in Figure 7, cables with three different dimensions of the cable insulation are used, arranged in three correspondingly dimensioned sections 54, 55 and 56, that is, in practice a modified cycle chain slot will be obtained. The figure also shows that the stator tooth 49 can be shaped with a practically constant radial width along the depth of the whole slot.

It is again pointed out that the winding sections denoted 54, 55 and 56 in Fig 7 correspond to the winding denoted 5d in Fig 5. In Fig 7 on the contrary, one or more windings corresponding to the control winding 9 in Fig 5 are denoted with the reference 40. These control windings 40 are in the embodiment located radially outermost from the rotor. It is pointed out that it is not necessary to locate the control winding 9 on the location denoted 40 in Fig 7.

In an alternative embodiment, the cable which is used as a winding may be a conventional power cable as the one described above. The grounding of the outer semiconducting layer 45 then takes place by stripping the metal shield and the sheath of the cable at suitable locations.

The scope of the invention accommodates a large number of alternative embodiments, depending on the available cable dimensions as far as insulation and the outer semiconductor layer etc. are concerned. Also embodiments with so-called cycle chain slots can be modified in excess of what has been described here.

As mentioned above, the magnetic circuit may be located in the stator and/or the rotor of the rotating electric machine. However, the design of the magnetic circuit will largely correspond to the above description independently of whether the magnetic circuit is located in the stator and/or the rotor.

As winding, a winding is preferably used which may be described as a multilayer, concentric cable winding. Such a winding means that the number of crossings at the coil ends has been minimized by placing all the coils within the same group radially outside one another. This also permits a simpler method for the manufacture and the threading of the stator winding in the different slots. Since the cable used according to the invention is relatively easily flexible, the winding may be obtained by a comparatively simple threading operation, in which the flexible cable is threaded into the openings 52 present in the slots 50.

Figure 8 shows a simplified and fundamental view of the electric field distribution around a winding of a conventional power transformer/reactor, where 57 is a winding and 58 a core and 59 illustrates equipotential lines, that is, lines where the electric

field has the same magnitude. The lower part of the winding is assumed to be at ground potential.

The potential distribution determines the composition of the insulation system since it is necessary to have sufficient insulation both between adjacent turns of the winding and between each turn and ground. The figure thus shows that the upper part of the winding is subjected to the highest insulation loads. The design and location of a winding relative to the core are in this way determined substantially by the electric field distribution in the core window.

The cable which can be used in the windings contained in the dry power transformers/reactors according to the invention have been described with assistance of Fig 1. The cable may, as stated before, be provided with other, additional outer layers for special purposes, for instance to prevent excessive electrical strains on other areas of the transformer/reactor. From the point of view of geometrical dimension, the cables in question will have a conductor area which is between 2 and 3000 mm^2 and an outer cable diameter which is between 20 and 250 mm.

The windings of a power transformer/reactor manufactured from the cable described under the summary of the invention may be used both for single-phase, three-phase and polyphase transformers/reactors independently of how the core is shaped. One embodiment is shown in Figure 8 which shows a three-phase laminated core transformer. The core comprises, in conventional manner, three core limbs 60, 61 and 62 and the retaining yokes 63 and 64. In the embodiment shown, both the core limbs and the yokes have a tapering cross section.

Concentrically around the core limbs, the windings formed with the cable are disposed. As is clear, the embodiment shown in Figure 9 has three concentric winding turns 65, 66 and 67. The

innermost winding turn 65 may represent the primary winding and the other two winding turns 63 and 64 may represent secondary windings. In order not to overload the figure with too many details, the connections of the windings are not shown. Otherwise the figure shows that, in the embodiment shown, spacing bars 68 and 69 with several different functions are disposed at certain points around the windings. The spacing bars may be formed of insulating material intended to provide a certain space between the concentric winding turns for cooling, bracing, etc. They may also be formed of electrically conducting material in order to form part of the grounding system of the windings.

No control windings 9 are drawn in Fig 9.

<u>Alternative cable designs</u>

In the cable variant illustrated in Fig 10, the same reference characters as before are used, only with the addition of the letter a characteristic for the embodiment. In this embodiment the cable comprises several electric conductors 42a, which are mutually separated by means of insulation 44a. Expressed in other words, the insulation 44a serves both for insulation between individual adjacent electrical conductors 42a and between the same and the surrounding. The different electrical conductors 42a may be disposed in different manners, which may provide for varying cross-sectional shapes of the cable in its entirety. In the embodiment according to Fig 10 it is illustrated that the conductors 42a are disposed on a straight line, which involves a relatively flat cross-sectional shape of the cable. From this it can be concluded that the cross-sectional shape of the cable may vary within wide limits.

In Fig 10 there is supposed to exist, between adjacent electrical conductors, a voltage smaller than phase voltage. More specifically, the electrical conductors 42a in Fig 10 are supposed to be

formed by different revolutions in the winding, which means that the voltage between these adjacent conductors is comparatively low.

As before, there is a semiconducting outer layer 45a exteriorly of the insulation 44a obtained by a solid electrical insulation material. An inner layer 43a of a semiconducting material is arranged about each of said electrical conductors 42a, i.e. each of these conductors has a surrounding inner semiconducting layer 43a of its own. This layer 43a will, accordingly, serve potential equalizing as far as the individual electrical conductor is concerned.

The variant in Fig 11 uses the same reference characters as before only with addition of the letter b specific for the embodiment. Also in this case there are several, more specifically three, electrical conductors 42b. Phase voltage is supposed to be present between these conductors, i.e. a substantially higher voltage than the one occurring between conductors 42a in the embodiment according to Fig 10. In Fig 11 there is an inner semiconducting layer 43b inwardly of which the electrical conductors 42b are arranged. Each of the electrical conductors 42b is, however, enclosed by a further layer 70 of its own, with properties corresponding to the properties discussed hereinabove with regard to the inner layer 43b. Between each further layer 70 and the layer 43b arranged thereabout, there is insulation material. Accordingly, the layer 43b will occur as a potential equalizing layer outside the further layers 60 of semiconducting material belonging to the electrical conductors, said further layers 70 being connected to the respective electrical conductor 42b to be placed on the same potential as the conductor.

Possible modifications

It is evident that the invention is not only limited to the embodiments discussed above. Thus, the man skilled within this art will

realise that a number of detailed modifications are possible when the basic concept of the invention has been presented without deviating from this concept as it is defined in the enclosed claims. As an example, it is pointed out that the invention is not only restricted to the specific material selections exemplified above. Functionally equal materials may, accordingly, be used instead. As far as the manufacturing of the insulation system according to the invention is concerned, it is pointed out that also other techniques than extrusion and spraying are possible as long as intimacy between the various layers is achieved. Furthermore, it is pointed out that additional equipotential layers could be arranged. For example, one or more equipotential layers of semiconducting material could be placed in the insulation between those layers designated as "inner" and "outer" hereinabove. It is again pointed out that it is normally not supposed to be necessary according to the invention to form the control windings 9 by means of such a flexible cable as the one discussed hereinabove as a consequence of the fact that the control winding or control windings are normally at a lower voltage than the rest of the windings of the electromagnetic device in question. More specifically, the rest of the windings may be true high voltage windings. For the rest it is pointed out that the exact control principle on execution of the method according to the invention may be varied in a variety of ways within the scope of control functions aimed at.

Claims

1. Electromagnetic device comprising at least one magnetic circuit (1) and at least one electric circuit (2, 3) comprising at least one winding (4, 5), the magnetic and electric circuits being inductively connected to each other and the device comprising a control arrangement (7) to control operation of the device, ***characterized*** in that the control arrangement (7) is adapted to control frequency, amplitude and/or phase as concerns electric power to/from the device by the control arrangement comprising means (9) for controlling the magnetic flux in the magnetic circuit, and that said at least one winding (4, 5) or at least a part thereof comprises at least one electric conductor (42) having an insulation system comprising an electric insulation (44) formed by a solid insulation material and interiorly thereof an inner layer (43), that said at least one electric conductor (42) is arranged interiorly of the inner layer (43) and that the inner layer has an electrical conductivity which is lower than the conductivity of the electric conductor but sufficient to cause the inner layer (43) to operate for equalization as concerns the electrical field exteriorly of the inner layer.

2. A device according to claim 1, ***characterized*** in that the control means comprises at least one control winding (9) inductively connected to the magnetic circuit.

3. A device according to claim 1 or 2, ***characterized*** in that the control arrangement (7) is adapted to control the reluctance in the magnetic circuit.

4. A device according to any preceding claim, ***characterized*** in that the control arrangement is adapted to add a magnetic flux addition to the magnetic flux in the magnetic circuit.

5. A device according to claim 3, ***characterized*** in that material having a permeability greater than 1 is included in the magnetic circuit and that the control arrangement (7) is adapted to control the reluctance in the magnetic circuit by varying the permeability of one or more such zones of the magnetic circuit which have variable permeability.

6. A device according to claim 5, ***characterized*** in that the zone or zones having a variable permeability comprise one or more gaps in the magnetic circuit.

7. A device according to any preceding claim, ***characterized*** in that the magnetic circuit is without magnetic core.

8. A device according to any of claims 1-6, ***characterized*** in that the winding is wound about a magnetic core (6).

9. A device according to claim 2 or one or more of the other claims, ***characterized*** in that the control winding (9) and the winding (4, 5) of the electric circuit are arranged to be passed by substantially the same magnetic flux.

10. A device according to any preceding claim, ***characterized*** in that the device forms a reactor adapted to control, by means of said at least one control winding, frequency, amplitude and/or phase as concerns the electric power flowing in the winding (4, 5) of the electric circuit.

11. A device according to any of claims 1-8 or 10, ***characterized*** in that the electric circuit (2) comprises at least two windings (23, 24) coupled in series, that the magnetic circuit comprises at least two alternative flux paths (18, 19), that said at least one control winding is adapted to control the magnetic flux to pass in any of or both of these flux paths and that the two windings of the electric circuit are located such that one of

them is capable of being switched off from magnetic flux by means of said at least one control winding.

12. A device according to any of claims 1-9 or 11, ***characterized*** in that the magnetic circuit is arranged in the stator or rotor of a rotating electric machine.

13. A device according to any of claims 1-9, ***characterized*** in that the magnetic circuit (1) belongs to a transformer having primary and secondary windings (4, 5) and that the primary and secondary windings and the control winding (9) are arranged to be passed by the same magnetic flux.

14. A device according to any of claims 1-8 in a transformer, ***characterized*** in that the secondary winding of the transformer comprises at least two winding parts coupled in series, that the magnetic circuit comprises at least two alternative flux paths (18, 19), that at least two occurring control windings (9b1, 9b2, 9c1, 9c2) are adapted to control the magnetic flux to pass in one or both of these paths and that the two winding parts of he secondary winding are placed such that one of them is capable of being switched off from magnetic flux by means of the control windings.

15. A device according to any of claims 11 and 14, ***characterized*** in that it comprises a magnetic core having at least three legs coupled in parallel and that two of these legs belong to different flux paths whereas the third is common to the two flux paths.

16. A device according to any preceding claim, ***characterized*** in that the insulation system exteriorly of the insulation comprises an outer layer (45) which has an electrical conductivity which is higher than that of the insulation to make the outer

layer capable, by connection to earth or otherwise a relatively low potential, of operating to equalize potential.

17. A device according to any preceding claim, ***characterized*** in that the outer layer is arranged to substantially enclose the electric field, arising as a consequence of said electrical conductor (42), inwardly of the outer layer (45).

18. A device according to any preceding claim, ***characterized*** in that the inner layer (43) and the solid insulation present substantially equal thermal properties.

19. A device according to any preceding claim, ***characterized*** in that the outer layer (45) and the solid insulation present substantially equal thermal properties.

20. A device according to any preceding claim, ***characterized*** in that said at least one conductor (42) forms at least one induction turn.

21. A device according to any preceding claim, ***characterized*** in that the inner and/or outer layer (43, 45) comprises a semiconducting material.

22. A device according to any preceding claim, ***characterized*** in that the inner layer (43) and/or the outer layer (45) has a resistivity in the range 10^{-6} Ωcm-100 kΩcm, suitably 10^{-3}-1000 Ωcm, preferably 1-500 Ωcm.

23. A device according to any preceding claim, ***characterized*** in that the inner layer (43) and/or the outer layer (55) has a resistance which per length meter of the conductor/insulation system is in the range 50 μΩ - 5 MΩ.

24. A device according to any preceding claim, ***characterized*** in that the solid insulation (44) and the inner layer (43) and/or the outer layer (45) are formed by polymeric materials.

25. A device according to any preceding claim, ***characterized*** in that the inner layer (43) and/or the outer layer (45) and the solid insulation (44) are rigidly connected to each other over substantially the entire interface to ensure adherence also on flexing and temperature change.

26. A device according to any preceding claim, ***characterized*** in that the solid insulation and the inner layer and/or the outer layer are formed by materials having a high elasticity to maintain mutual adherence on strains during operation.

27. A device according to any preceding claim, ***characterized*** in that the solid insulation and the inner layer and/or the outer layer are formed by materials having substantially equal E-modulus.

28. A device according to any preceding claim, ***characterized*** in that the inner layer (43) and/or the outer layer (45) and the solid insulation (44) are formed by materials presenting substantially equal thermal coefficients of expansion.

29. A device according to any preceding claim, ***characterized*** in that the conductor (42) and its insulation system constitutes a winding formed by means of a flexible cable (41).

30. A device according to any preceding claim, ***characterized*** in that the inner layer (43) is in electric contact with the at least one electric conductor (42).

31. A device according to claim 30, ***characterized*** in that said at least one electric conductor (42) comprises a number of strands and that at least one strand of the electric conductor (42) is at least in part uninsulated and arranged in electric contact with the internal layer (43).

32. A device according to any preceding claim, characterized in that the conductor (42) and its insulation system is designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV and preferably more than 72,5 kV.

33. A machine according to claim 12, ***characterized*** in that the magnetic circuit comprises one or more magnetic cores (48) having slots (50) for the winding (41).

34. A device according to any of claims 12 and 32-33, ***characterized*** in that it is constituted of a generator, motor or synchronous compensator.

35. A device according to any of claims 12 and 33-34, ***characterized*** in that it is directly connected to a power network for high voltage, suitably 36 kV and more, without intermediate transformer.

36. A device according to any of claims 1-11 and 13-32, ***characterized*** in that it is constituted by a power transformer/reactor.

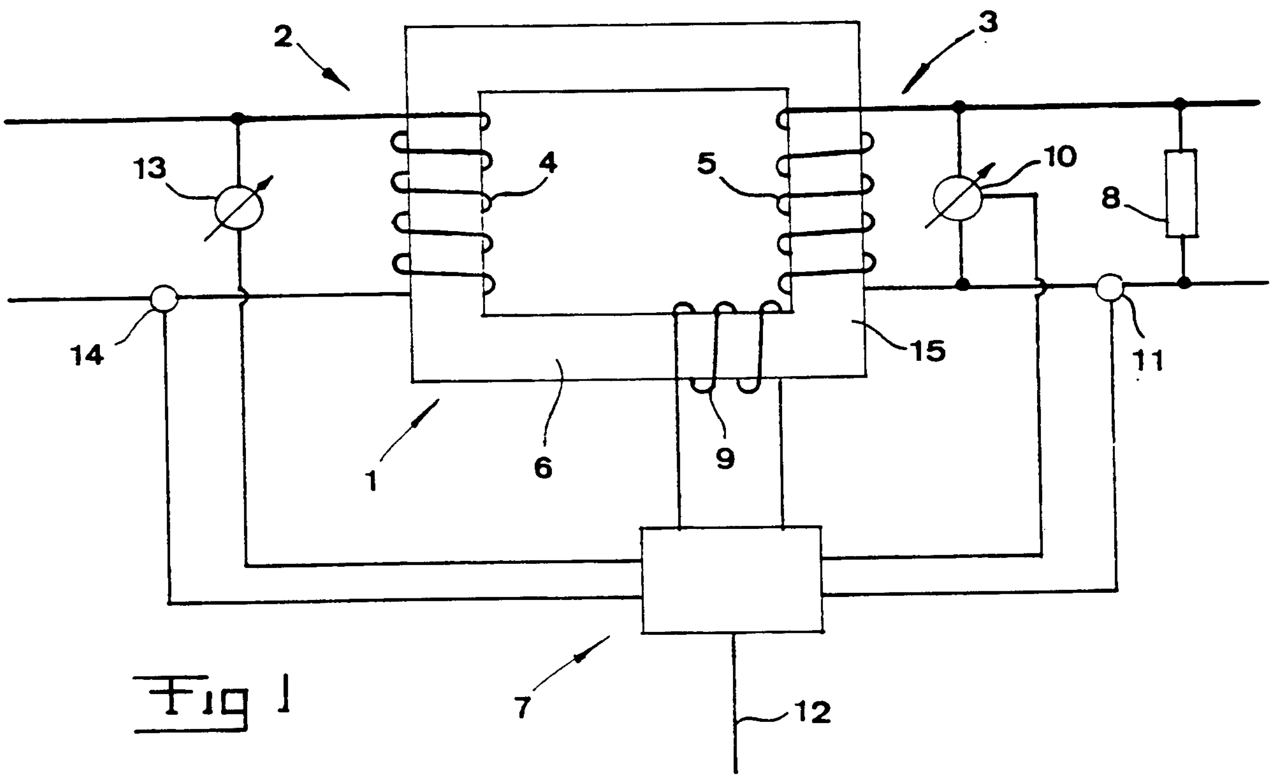

Fig 1

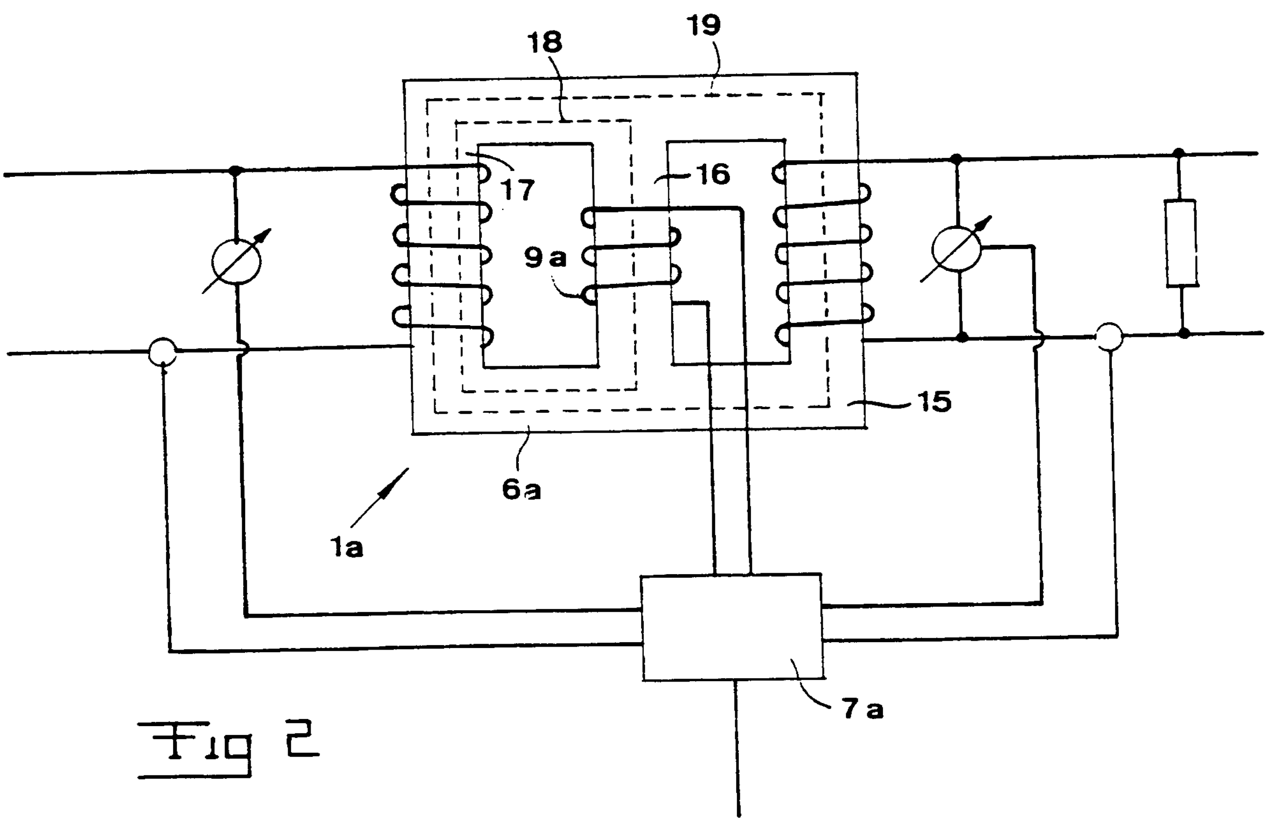

Fig 2

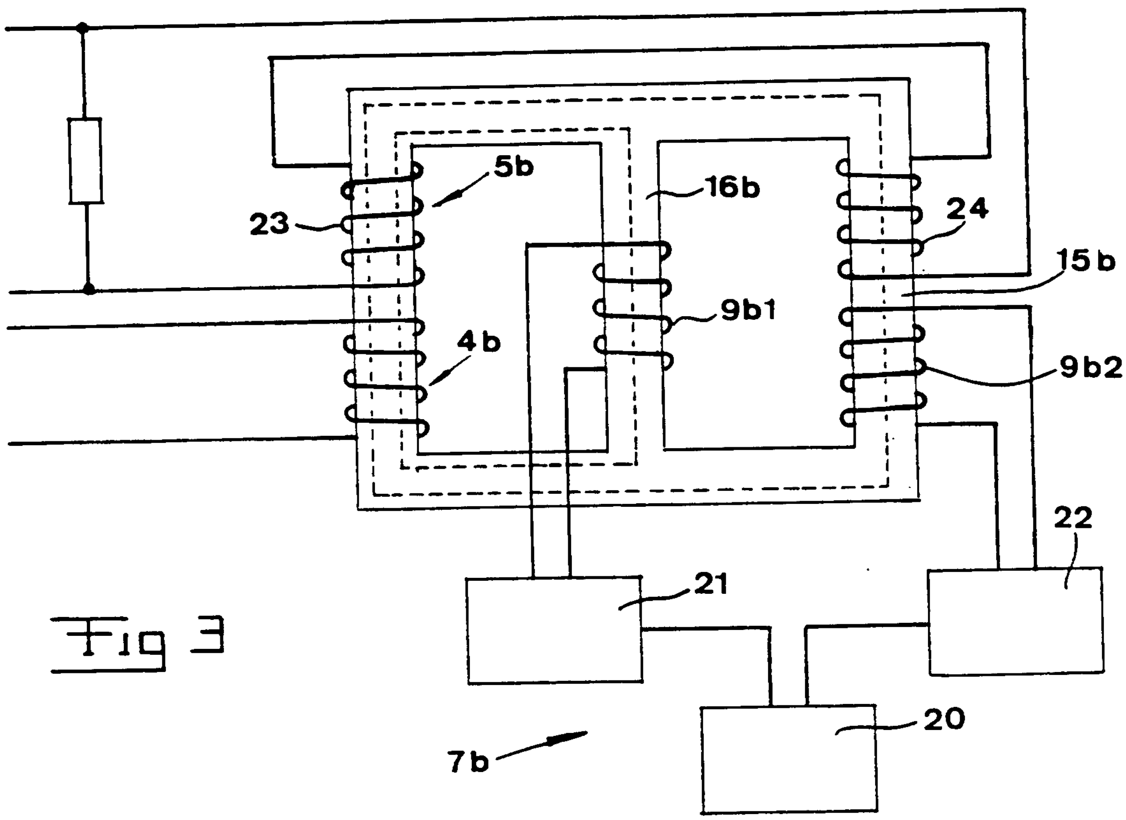
5b
16b
23
24
15b
9b1
4b
9b2
22
21
20
7b

Fig 3

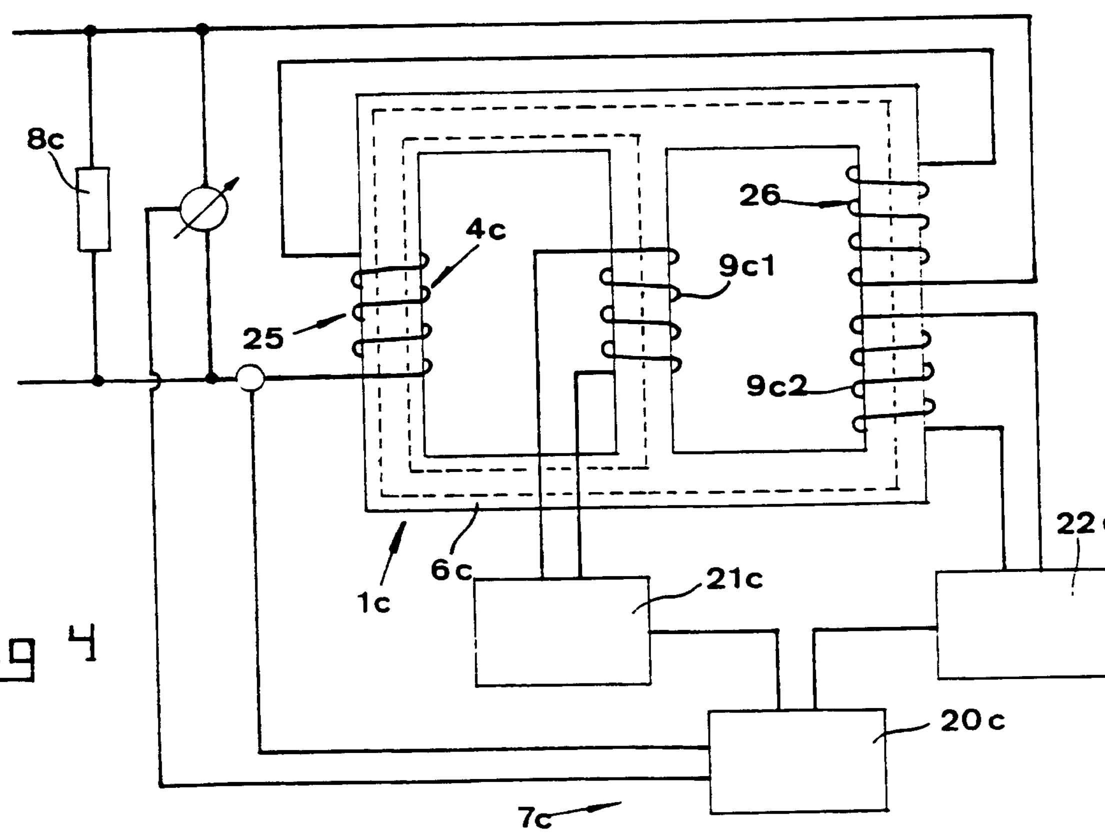
8c
26
4c
9c1
25
9c2
22c
6c
21c
1c
20c
7c

Fig 4

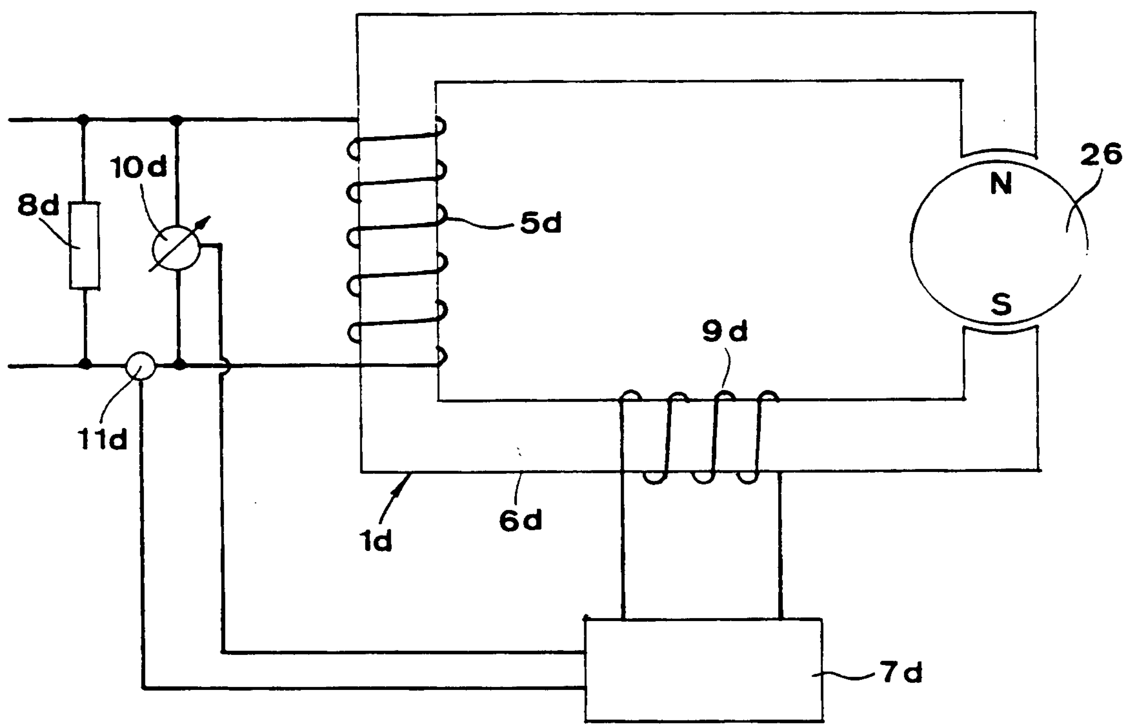

Fig 5

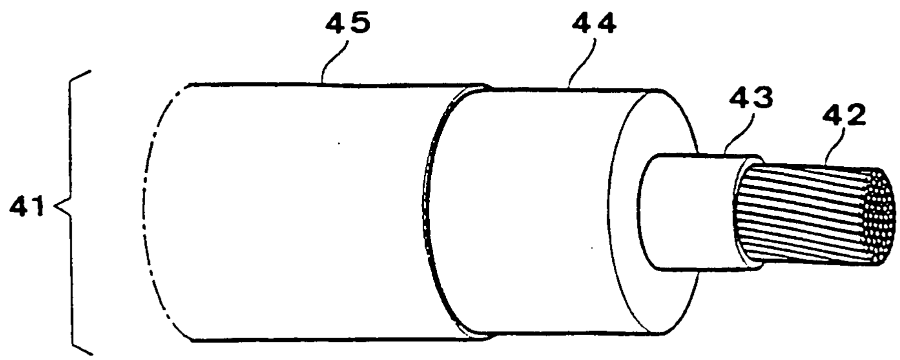

Fig 6

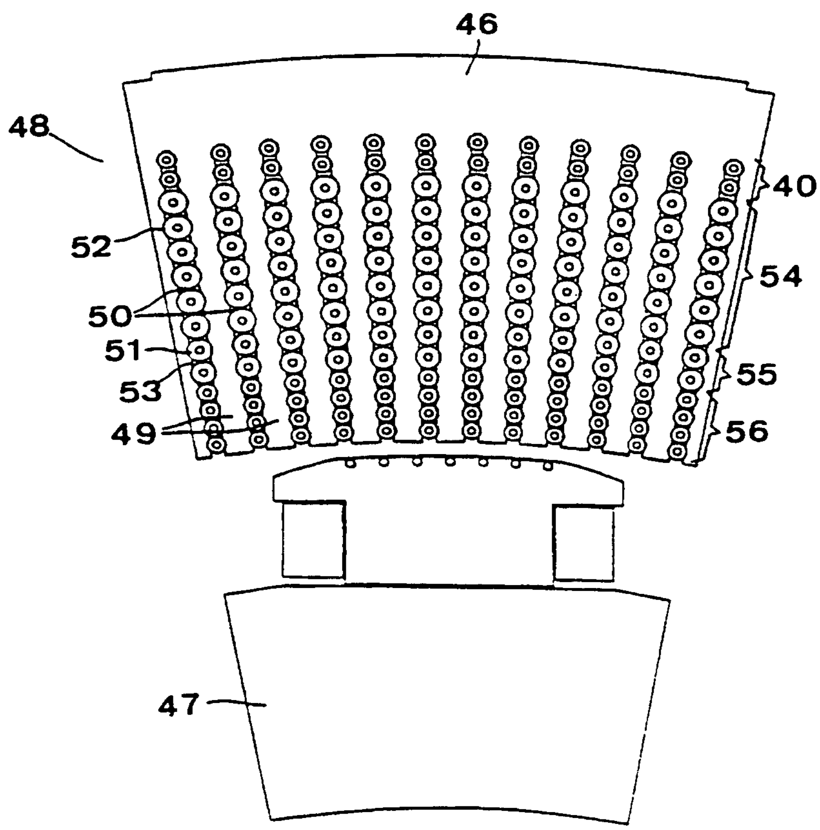

Fig 7

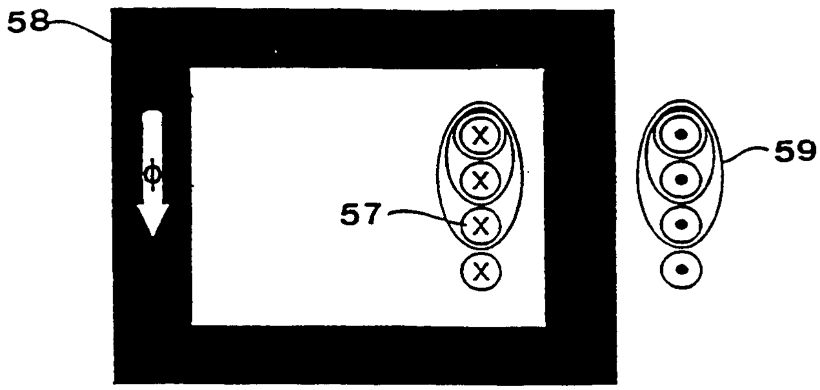

Fig 8

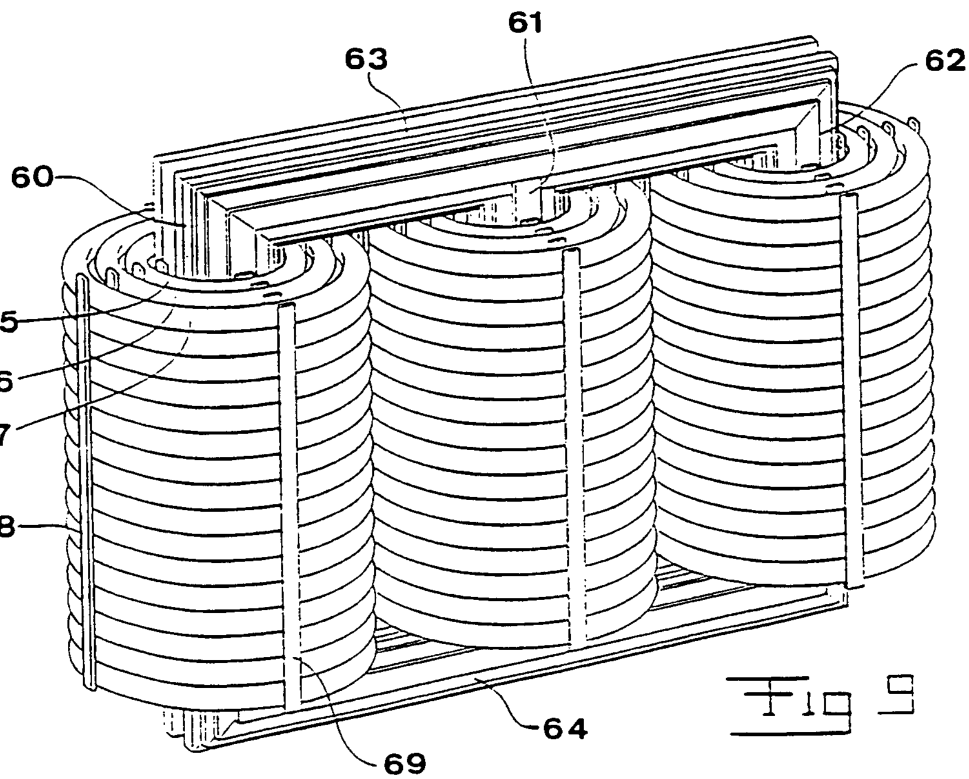

Fig 9

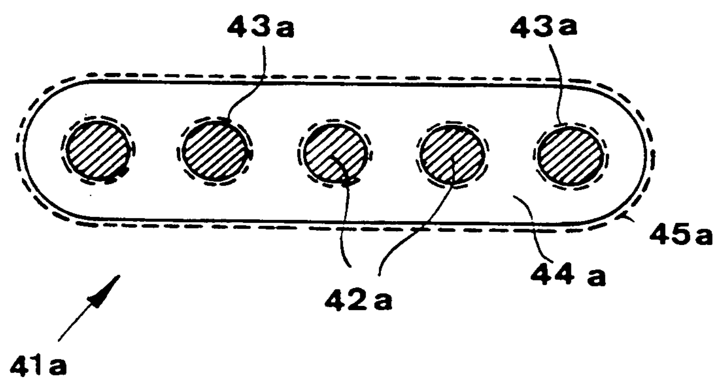

Fig 10

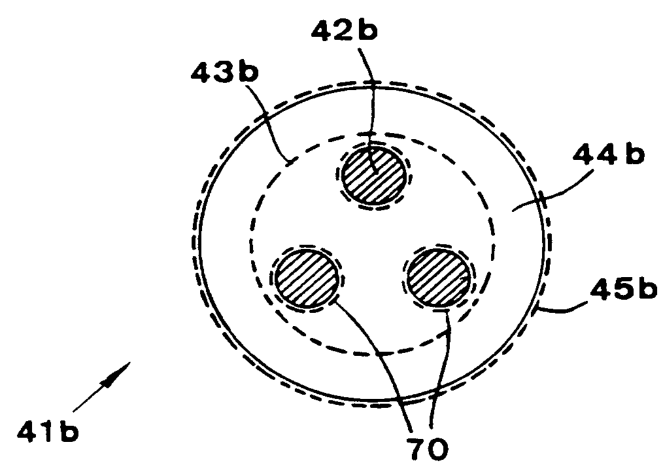

Fig 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01733

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01F 27/32, H02K 3/30
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F, H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5036165 A (RICHARD K. ELTON ET AL), 30 July 1991 (30.07.91), abstract --	1
A	US 4109098 A (MATS GUNNAR OLSSON ET AL), 22 August 1978 (22.08.78), abstract -- --------	1

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 March 1999	01-04-1999

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Magnus Westöö Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/99

International application No.
PCT/SE 98/01733

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5036165 A	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
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US 4109098 A	22/08/78	AR 211382 A	15/12/77
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		JP 50109479 A	28/08/75
		NL 7501168 A	04/08/75
		SE 384420 B,C	03/05/76
		SE 7401244 A	01/08/75

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 670 288 A1**

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(21) Application number: **94830024.9**

(51) Int. Cl.[6]: **C02F 1/48**

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(54) **Magnetic resonance scale preventer-decalcifier, connected to a transformer of the controlled reluctance type.**

(57) Scale preventer/decalcifier device for the treatment of water which is hard and otherwise, based on the use of magnetic fields of variable frequency and intensity, generated by a trio of coils wound round the pipework in which the water which acts as a resonant nucleus flows, the said coils being connected to the secondary of a controlled reluctance transformer. The signal generated by the coils is variable both as a pulse and as an amplitude, which are determined by the type of water flowing through the pipework, thereby preventing the formation of calcium carbonate.

EP 0 670 288 A1

The invention relates to a scale preventer/decalcifier device involving magnetic resonance, variable in terms of intensity, amplitude and frequency, supplied by a transformer of the controlled reluctance type.

It is known that the use of hard water, both for domestic consumption and industrial applications, creates serious problems resulting from the deposit of lime whenever the water, when heated, converts part of the calcium bicarbonate it contains into insoluble calcium carbonate.

In an attempt to eliminate or at least mitigate this phenomenon, various systems have been used in the past, primarily based on the use of chemicals (phosphates) or physico/chemical products (ion exchange resins) which do, however, have a variety of disadvantages related to high plant and maintenance costs. In fact, the chemicals cause the quality of the water, particularly for domestic consumption purposes, to deteriorate, also causing conditions of environmental pollution, whilst the physico/chemical products cause an actual demineralization which makes the water unsuitable for domestic consumption purposes.

In recent times the use has also been known of electro-physics systems, such as permanent magnets or electromagnets, which enable almost acceptable results to be obtained but only if the treated water is of medium hardness, not more than 40 degrees French. Furthermore, this apparatus does not permit a variable molecular magnetization to be obtained which persists over time and in direct relation to the quantity of treated suppliable liquid, nor does it prevent the conversion of bicarbonate into aragonite or varetite.

The object of the invention is to permit the manufacture of a scale preventer/decalcifier device which is simple, reliable, with no limits as to size and of modest cost, to be used to treat water of any hardness and also at elevated temperatures, which prevents the conversion of the bicarbonate in solution into insoluble calcium carbonate and which permits the dissolution of the lime already built up on the walls of the pipes through the persistence in the liquid of the molecular magnetization effect.

This and other objects which will emerge in greater detail below are all achieved by the scale preventer/decalcifier device which is the object of the invention which is characterized in that it comprises in combination a preferably controlled reluctance transformer of known type and three low voltage resonance coils, coaxial with the pipework in which the water flows, directly connected to the secondary of the controlled reluctance transformer and prevented from operating during negative half cycles by means of a rapid commutation rectifier.

The water flowing through the pipework comprises a nucleus resonating at the signal coming from the triple coil and through the effect of aggregating polarization or decreasing ionization it maintains the equilibrium according to the following formula:

$$Ca(HCO_3)_2 = CaCO_3 + H_2O + CO_2,$$

preventing the formation of calcium carbonate even at elevated temperatures.

Further objects and advantages will emerge from the description below and from the accompanying drawings which show an embodiment of the invention in a diagrammatic manner by way of example with reference to the accompanying drawings in which:-

Fig. 1 shows the diagram of a controlled reluctance transformer;

Fig. 2 shows a trio of coils wound round a steel pipe;

Fig. 3 shows the wiring diagram for connecting the said coils.

A controlled reluctance transformer is produced by winding a first primary winding P1 clockwise round a core N and a second primary winding P2 anticlockwise around the core N; the secondary winding S also being wound round the said core N.

The primary windings P1 and P2 are made of copper wire of suitable cross-section from a 220 V mains supply and are connected together according to the diagram x-y and u-z with the potential difference being subtracted. The secondary winding S is also made of copper wire and the number of turns of the secondary are such that 9 V is supplied to output terminals S' and S'' which are directly connected to inputs A-B of resonance coils (Fig. 2).

Resonance coils L1, L2 and L3 are wound round Teflon formers of suitable diameter and bore, and are mounted coaxial with pipe T, Specifically, coils L1 and L3 are single windings and produced with an equal number of copper wire turns while coil L2 is made with two windings equivalent in terms of number of turns, each equal to half the number of turns relative to coil L1 or L3. The windings of coil 2 are wound in the opposite direction with respect to the other.

The three coils L1, L2 and L3 are also connected to an alternating supply and interconnected by a rapid commutation single phase rectifier D which has the effect of damping the reversel peaks of the alternating supply. The rectifier is preferably in the form of a semiconductor diode.

The supply is via the secondary of the transformer at low voltage and alternating current, with no polarized capacitive filters. By altering the relative magnitude of the voltages in the primary windings P1 and P2, the coils L1, L2 and L3 can be made resonate at different frequencies due to alter-

ation of the amplitude of the alternating signal in the coils L1, L2 and L3 and by the relative length of the positive half wave as compared with the length of the negative half wave as affected by the rectifier D.

Practical trials carried out at specialist laboratories have demonstrated the efficacy of the decalcifier device that is the object of the invention. The invention, which is illustrated and described in a diagrammatic manner by way of example, should be considered to be expandable to those additional variants which, as such, come within its scope.

Claims

1. A magnetic resonance decalcifier device, characterized in that it comprises a controlled reluctance transformer (P1, P2, P3) the primaries (P1, P2) of which comprise two windings connected in parallel and wound in the opposite direction; a trio of resonance coils (L1, L2, L3), coaxial to a pipe (T) through which water which comprises a resonant nucleus is arranged to flow, and the rectifier (d); a semiconductor capable of damping the reversal peaks in the resonance coils.

2. A device, according to claim 1, characterized in that the said trio of coils comprises two single-winding coils (L1,L3) which are equal and located laterally to a third coil (L2) with a double winding which is inverted and resonates at variable frequencies.

3. A device, according to claims 1 and 2, characterized in that the said coils (L1,L2,L3) are connected between phase and counterphase by the said rectifier (D) which causes a half-wave cut at the variable frequencies.

4. A device, according to claim 1, characterized in that it is supplied with alternating current at low voltage without the use of polarized capacitive filters.

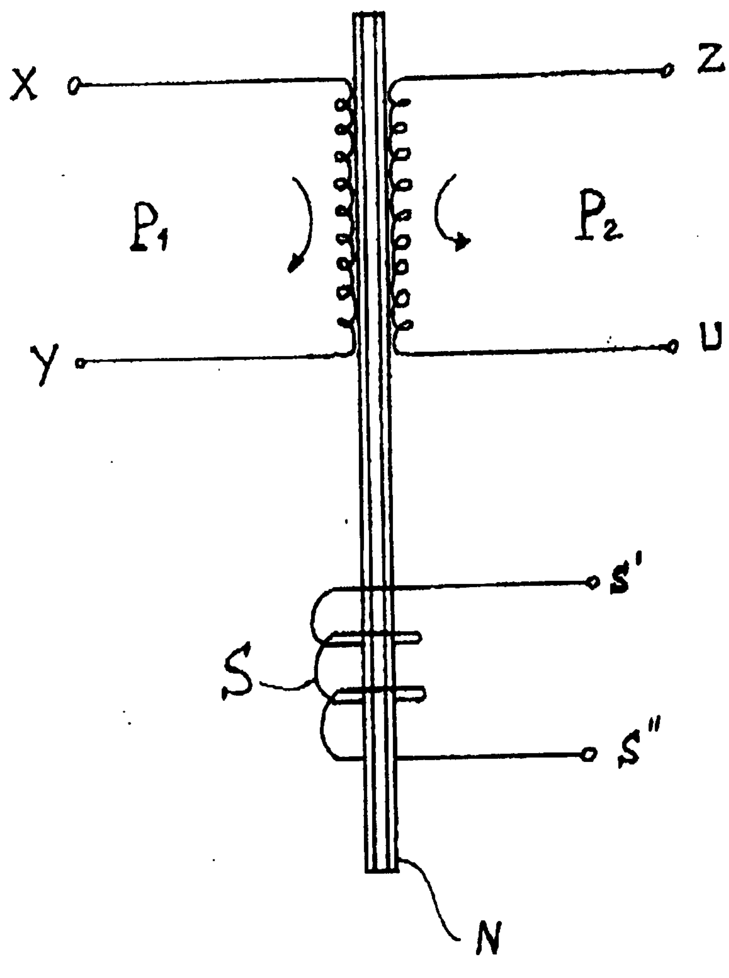

FIG. 1

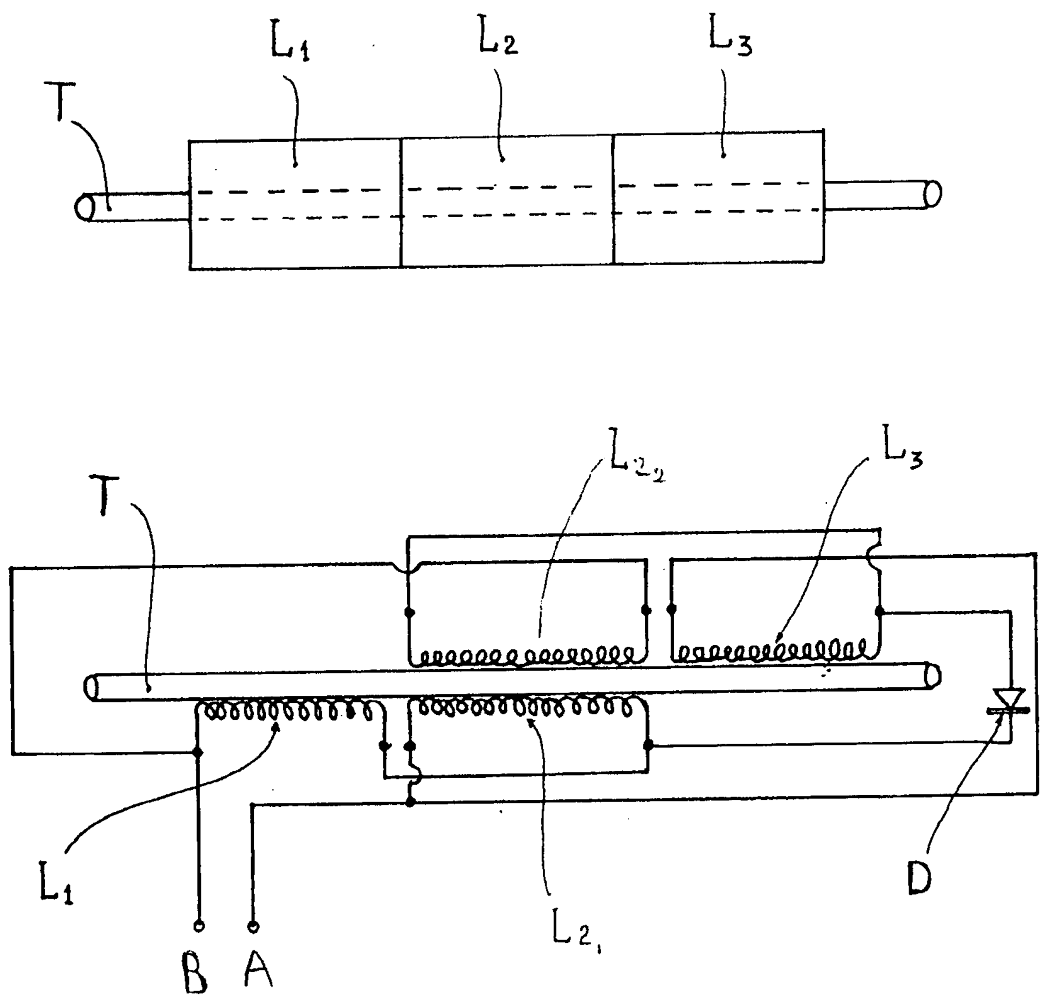

FIG. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 83 0024

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	BE-A-560 035 (NICOLARDOT,P.G.R.) * page 7, line 18 - page 8, line 19 * * page 11, line 9 - line 30 * * page 16, line 1 - line 17; figure 6 * ---	1	C02F1/48
A	WO-A-88 05763 (NIESSEN,P.) * claims 1-3 * ---	1,4	
A	BE-A-1 002 892 (REWAT LTD.) * page 4 - page 5 * -----	1-4	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

C01F
C02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 July 1994	Gonzalez Arias, M

CATEGORY OF CITED DOCUMENTS

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L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(32) Priority Date: 26 January 1981 (26.01.81)

(33) Priority Country: US

(71)(72) Applicant and Inventor: CARILLO, Ernie [US/US]; 1619 Whitestone Road, Spring Valley, CA 92077 (US).

(74) Agents: CHARMASSON, Henri, J. A. et al.; 4550 Kearny Villa Road/Suite 202, San Diego, CA 92123 (US).

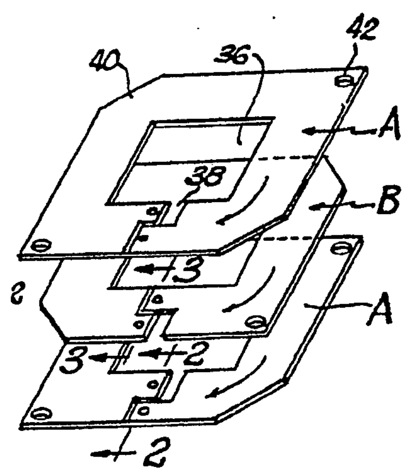
(81) Designated States: AT (European patent), AU, CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, KP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: ELECTRICAL REACTOR CONSTRUCTION

(57) Abstract

The winding of wire to create a coil is complex from an equipment and manufacturing standpoint. Once manufactured, there is little latitude for the on-site user to alter or fabricate a coil according to specific needs. A system of creating coils, windings, inductors and capacitors utilizes wafer stacks having suitable pass-throughs (48) and voids (50) in the insulation portion of the wafer permits one of several different types of these electrical elements to be made according to the particular orientation and order in which the wafers are stacked; each wafer comprises a thin insulator panel (A, B) with a conductive film across one surface, which could possibly be created photographically.



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Electrical Reactor Construction

Description

Background of the Invention

The invention is in the field of electrical coils, windings, and reactors including capacitors and inductors, although it particularly applies to inductor construction.

Typically, coils, windings and inductors are made by winding continuously a wire or wires around an iron core or hollow core depending on the use. This is a process that naturally requires a certain amount of finesse, especially in the making of large inductance elements. In spite of the fact that a great many electrical and electronic components are now made solid state or photographically, typically coils and windings are still created in the same traditional manner of winding the wire about a core.

Aside from the manufacturing complexity of the wire technique, also generally speaking the winding inductor, or capacitor, must be pre-tailored to a specific magnetic strength, resistance, inductance or capacitance, qualities which aside from elements, specifically manufactured to be variable, cannot be easily adapted on site to particular specifications.

Summary of the Invention

The present invention solves the above stated problem by providing wafer elements each constituting an insulator panel on which a film of conductor is photographically or otherwise applied

and shaped, with these wafers being collated or stacked to create the particular element desired without requiring any winding. In the several different embodiments, in addition to the general purpose laminarly-constructed wafer coil, are units which may be alternatively arranged to define an inductor or capacitor, one embodiment which may be utilized as an inductor with either a single coil or multiple coaxial coil with the same number of wafers, and yet another embodiment in which a single wafer type can be stacked alternately in upright and inverted position to create an inductor.

One advantage in this type of construction is the simplicity of the actual assembly of the wafers wherein once the wafers have been made, they can be assembled into a coil of any desired coil length without any special equipment. Thus, in addition to completely eliminating the wire winding the equipment required to make a conventional coil, the on-site user is able to determine the electrical qualities required and fabricate a coil very quickly and simply from a supply of wafers, and alternatively in at least one embodiment shown herein, the end user may also rearrange the same wafers, and with the addition of a couple of insulator sheets, create a capacitor rather than an inductor or coil so that the same unit may combine capacitance and inductance to form a filter or resonant

circuit in a single component.

Brief Description of the Drawings

Figure 1 is a perspective view of a stack of two alternate wafer types;

Figure 2 is a section taken along line 2-2 of Figure 5;

Figure 3 is a section taken along line 3-3 of Figure 7;

Figure 4 is a perspective view of a completed coil stack according to the scheme of Figure 1;

Figure 5 is a top elevation view of a fragment of a type (a) wafer;

Figure 6 is a top elevation view of a fragment of a type (a) wafer upside down;

Figure 7 is a top elevation view of a fragment of a type (b) wafer;

Figure 8 is a top elevation view of a type (b) wafer upside down;

Figure 9 is a section of the connections between three adjacent wafers in an inductor stack such as Figure 4;

Figure 10 is a section taken along line 10-10 of Figure 7;

Figure 11 is a perspective view of a fragment of a type (a) insulator;

Figure 12 is a similar view of a type (b) insulator;

Figure 13 is a perspective exploded view of a typical stack of elements used to form a capacitor;

Figure 14 is a diagrammatic fragmentary view of a modification of the wafer;

Figure 15 is a section taken along line 15-15 of Figure 14;

Figure 16 is a diagrammatic view of the electrical connections in an inductor made from wafers shown in Figures 14 and 15;

Figure 17 is yet another embodiment of wafer;

Figure 18 is a section taken along line 18-18 of Figure 17;

Figure 19 is a top elevation view of a type (b) wafer of a general type shown in Figure 17;

Figure 20 is a section taken along line 20-20 of Figure 19;

Figure 21 is an exploded perspective of an inductor configuration made from unmodified wafers of the type shown in Figures 17 and 19;

Figure 22 is a section taken through a typical stack made according to Figure 21;

Figure 23 is a section of a typical stack wherein the intermediate conductor bridges are broken and intermediate conductor rivets are installed; and

Figure 24 is a perspective view of a typical lead wire arrangement.

Figure 25 is a section of a typical capacitor pass-through made according to the disclosure.

Detailed Description of the Preferred Embodiments

The principal concept of the invention is that wafers be provided that are so cut, and that have conductor films on their surfaces that are so contoured, that the wafers may be assembled in a stack to provide a single coil or winding, or in some instances concentric coils, or in some instances capacitors. The wafers shown in the first sheet of drawings are provided in two different types, which are identified as type (a) and type (b), and can be used to define a winding or coil simply by alternating (a)-(b)-(a)-(b)-, etc., or by the utilization of two additional insulator films with the proper orientation these wafers can be reorganized to define a capacitor.

Figure 5 indicates at 20 a type (a) wafer of the first embodiment. This wafer has an insulator panel 22 and a conductive film 24 which is shaped around the peripheral areas of the insulator 22, to define a broad conductive loop with adjacent end points 26 and 28 that respectively define a receiving contact 30 which may be contacted from above by another wafer, and a pass-through contact 32 which passes through an aperture 34 as best seen in

Figure 2 to make contact with the receiving contact 30 of a subsequent wafer. It should be noted to clarify the relations in the drawings that the insulative panel 22, which is a rigid form-defining member, may be a continuous flat panel with no apertures other than the aperture 34 for electrical pass-through, in which instance the coil would have no hollow core. However, in the instant embodiment, to make the first illustrated embodiment universally applicable, a central core opening 36 is made through the insulator 22 so that it penetrates the entire panel 20, and an additional adjoining void 38 also passes completely through the insulator as well as the conductor, which as will be understood below, is inoperative in a coil configuration but permits the wafers to be arranged to define a capacitor as well. It should also be noted that the flats 40 and the assembly holes 42 best seen in Figure 1 have no function other than identification of the wafer and permitting the easy assembly thereof.

Whereas the central core opening 36 and the void 38 pass completely through the insulator, the ends of the conductive inductor 24 must be separated, at least in the coil embodiment, by a narrow open channel 44. This channel need not pass through the insulator, as it would only weaken the structure.

The second type of wafer is the type (b) wafer shown in Figures 7 et seq which is substantially identical to the first wafer and will be re-numbered only to identify the receiving contact 46, the pass-through contact 48 and the void 50. Both wafers have a longitudinal axis 52 about which they can be rotated for re-orientation in the capacitor assembly described below.

The pass-through conductors 32 and 48 are preferably formed by an extension of the conductive material from the film 24 and define a thin, rivet-shaped contact 54 shown in Figures 2, 3 and 9. Any other suitable pass-through conductor could be used.

Turning now to the combination of the type (a) and type (b) wafers necessary to create a coil, it can be seen from Figure 1 that all that is necessary is to alternate type (a) and type (b) in a stack. Due to the configurations of these two variant wafers, the pass-through makes contact to maintain the same rotational direction of current flow like a coiled wire, which is clockwise as seen from the top in Figure 1. These wafers may be assembled in any number desired, with the contacts automatically being made as shown in Figure 9, such that a stack shown in Figure 4 may be created. This stack may be held together with bolts through the assembly holes 42, and a central core 56 could be inserted as shown. This core could, of course, also be rectangular or horseshoe-shaped, or even

a bar, and inductively couple a secondary stack so that a transformer is created. The coil could be geometrically modified in any desireable fashion within the bounds of the wafer concept to create windings for motor or generator stator or armature windings, or coil resistors, cathode ray deflector coils, or for any other application calling for a coil or winding.

It is thus clear that the user of the coil may modify at will by unbolting the stack the amount of resistance, inductance and magnetic flux capability inherent in his element. He also may utilize the same wafer configuration to create a capacitor, as shown in Figures 11 through 13. The only additional elements required to create a capacitor are two types of insulator layers, type (a) and type (b) which have cutouts at 58 and 60 respectively. When these insulative layers are arranged in the configuration shown in Figure 13, each insulator on the respective wafer passes through the adjacent wafer to contact the once removed insulator so that the wafers leapfrog in overlapping fashion connecting alternate conductors together to define two separate interstitially alternated conductor groups.

To clarify this relation, in Figure 13 the top layer is a type (a) wafer turned upside down followed by a type (a) insulator, a right side up (a) wafer, an upside down (b) wafer, a (b) insulator,

and a right side up (b) wafer, and so forth. A little study will reveal that this is essentially an (a)-(b)(a)-(b) style coil arrangement with an identical arrangement turned upside down and shuffled into the first stack, with the facing conductors being separated by added insulators where necessary. Each pass-through would pass through not only its own insulator but also an adjacent conductor and insulator, so that special pass-throughs 62, indicated in Figure 25, would need to be used. These could be provided as rivet inserts which could be inserted into the standard pass-throughs of the type (a) and (b) wafers to avoid requiring specialized construction.

The above stated arrangement sets forth two basic styles of wafer, that is type (a) and type (b), that can be combined to create either a coil or capacitor with slight modification. Of course, there are many variations of this, utilizing the same basic configuration including a solid, uninterrupted insulator without a central core opening 36, with the central portion being covered with the conductor film and the elimination of the channel 44 if the wafer is adapted exclusively for use as a capacitor. Conversely, if the wafer is to be used exclusively in an inductor or other coil assembly, the voids 38 can be omitted and several other styles of terminal patterns on the wafers could be used.

It would still be necessary to use two different types, type (a) and type (b), of wafer in order to insure that the current continues in either the clockwise or counterclockwise direction without reversing itself from wafer to wafer. This would be true in an insulator-conductor wafer, although it could be avoided as indicated in Figures 14 through 16 if a double-insulated conductor sandwich is used. In this implementation, as shown in Figure 15, the sandwich 64 comprising upper and lower insulators 66 and 68 has a central conductor 70 and up and down pass-throughs 72 and 74 permits a single wafer type to be used for the entire coil construction with it being flipped alternately upside down about a longitudinal axis to achieve the configuration shown diagrammatically in Figure 16. The disadvantage of this embodiment, of course, is that it does not accord itself to standard photographic electronic component production wherein a conductor film is established on a single rigid insulative substrate.

Turning to yet another embodiment illustrated in Figures 17 though 23, it would, of course, be possible to modify the above described coil type by replacing the single conductor loop per wafer, with two or more loops which are either wound in series, or define separate loops which connect to adjacent, corresponding separate loops with pass-throughs. An illustration of a combination of both

these alternatives is shown in wafers 76 of Figures 17 and 19. These wafers, being provided in type (a) and type (b) for the same reason stated above, utilize dual conductors 78 with intermediate contact points 80 defining receiving and pass-through connection points connected with a breakable bridge 82. In the configuration shown in Figures 17 through 20 the bridge is not broken and a standard conductor configuration similar to that shown in Figures 1 and 4 is established, except each wafer is double-wound, is shown. In order to create a coaxial pair of windings out of a single wafer stack, the bridges 82 are broken and a rivet-like pass-through connector 84 is pressed into the pre-drilled holes in the insulator to create a double coil as best seen in Figure 23.

In this last embodiment as in the others it is, of course, necessary to take off lead wires from certain of the wafers, and such a specialized wafer is shown in Figure 24 at 86 wherein lead wires 88 are connected to the appropriate terminals and exit the wafer in any suitable manner.

Other variations would include the possibility of using half or partial coils, particularly in the embodiment shown in Figure 4, in which a core is used and the half coils might be press-mated together around the existing core to define the coil. Additionally, ceramic

insulators could be used, and in the event a capacitor alone is desired, a single element could be used with suitably positioned voids and contacts such that it could be flipped alternately upside down as as are wafers and the element in Figures 14 through 16 to create a capacitor. Wafers could be designed that could be ganged in parallel in groups of two or more to make high current windings, and the same basic technique could be used by arranging parallel conductor panels in a jig with suitable connections being made, and pouring in a liquid dialectric which would solidify to a solid mass, or remain liquid.

In any of its implementations, the invention sets forth a convenient style taking advantage of current manufacturing techniques for the creation of a wide variety coils, windings, resistors and reactive devices and even deflective coils such as for cathode ray tubes. In addition to those shown above, virtually any combination of current carrying capacity, concentrically wound multiple secondary transformers, and unitary filters and oscillator units can be created.

1. A superimposed wafer electrical element comprising:

(a) a series of wafers each having an insulative sheet and a conductor layer bonded to said insulative sheet;

(b) portions of said insulative sheet being removed to define at least one pass-through aperture and having a contact electrically connected to said conductor layer and passing through said aperture; and

(c) said wafers being arranged in a stack such that by virtue of the electrical integrity established by the contact of each wafer contacting the subsequent wafer in said stack, an electrical element having pre-determined properties is created.

2. Structure according to Claim 1 wherein:

(a) said conductive layers define at least one continuous conductor forming at least one open loop having a first and a second end point;

(b) each of said wafers defines said conductor end points in substantially the same locations as the end points of every other of said wafers;

(c) said wafers fall into two groups, a first group having a contact contacting said first end point and passing through said

insulative sheet, and a second group having a contact contacting said second end point and passing through said insulative sheet and the conductors of each group traversing mutually angularly oppositely directed paths from said first to said second endpoint;

(d) said wafers being arranged in a stack alternating wafers from group 1 and group 2 such that a contact from each group 1 wafer contacts the first end point of the conductor of the subsequent group 2 wafer which has a contact on its second conductor end point contacting a subsequent group 1 wafer on its first conductor terminal, and so forth such that a continuious coil is formed with all loops looping in the same rotational direction to define a coil.

3. Structure according to Claim 2 wherein each of said conductors defines a coil of at least 750^{o} having a second pair of end points intermediate said first and second end points, and connected by a breakaway bridge such that said conductor may be operated as a single coil or, by breaking of said bridge, as two separate coils.

4. Structure according to Claim 3 and including pass-through apertures disposed beneath said intermediate end points and pass-through rivets installable in pairs to connect to said intermediate pair of endpoints to contact through the last mentioned apertures intermediate endpoints

of adjacent wafers to create two separate coaxial coils when said bridges are broken.

5. Structure according to Claim 2 wherein said contact comprises an integral pass-through extension of said conductor layer.

6. Structure according to Claim 2 wherein said wafers each define a central opening mutually aligned in said stack such that the coil defined by said stack can be selectable used as a hollow-core inductor or having a core inserted through said central opening.

7. Structure according to Claim 1 wherein each of said wafers has a complete void therethrough and said contacts are positioned on each wafer to pass through the void of the adjacent wafer and contact the wafer once removed, whereby a capacitor is created.

8. Structure according to Claim 1 wherein:

(a) said wafers may be flipped about a rotational axis for stacking, and said wafers fall into two types arranged relative to the rotational axis as follows:

(b) a type (a) wafer having receiving and pass-through contacts in a row parallel to and on one side of said axis and a void positioned

at the virtual image of said receiving contact on the opposite side of said axis;

(c) a type (b) wafer having pass-through and receiving contacts positioned to align with the receiving and pass-through contacts of said type (a) wafers respectively, and defining a void positioned at the virtual image of said receiving contact on the opposite side of said axis, and including two insulator sheets, type (a) insulators having a void coincident with the receiving contact and the void of said type (a) wafers, and type (b) insulators having a void coinciding with the receiving contact and void of said type (b) wafers, whereby said wafers may be alternately stacked to create a coil, or alternatively stacked in the following order to create a capacitor: Type (a) wafer, type (b) wafer upside down, type (b) insulator, type (b) wafer, type (a) wafer upside down, type (a) insulator, with this pattern repeating as desired.

9. Structure according to Claim 1 and including a second insulative sheet bonded to the opposite side of said conductive layer than the first mentioned sheet, and said conductor defines a loop with a first and second end point exposed through apertures in respective ones of said insulative sheets and being so positioned as to reverse places when said wafer is turned upside down, whereby said wafers when stacked with alternate wafers upside down create a coil.

1/3

FIG. 5

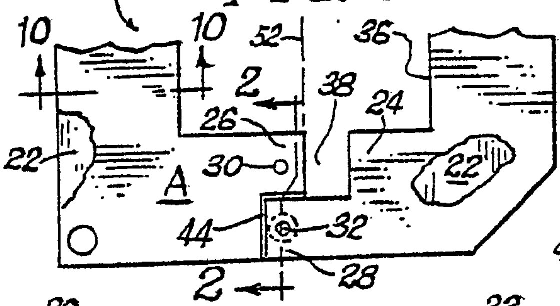

FIG. 2

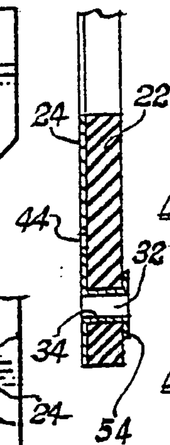

FIG. 1

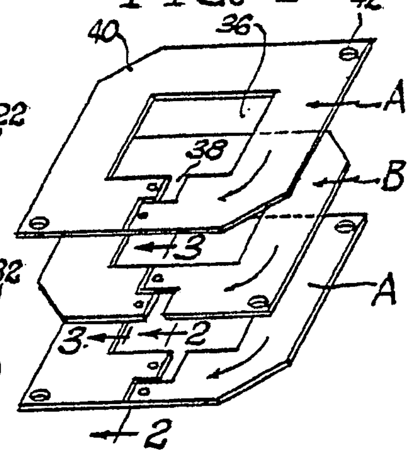

FIG. 6

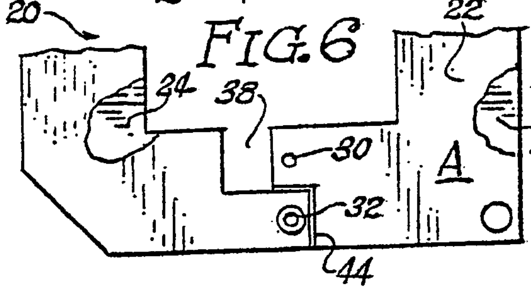

FIG. 7

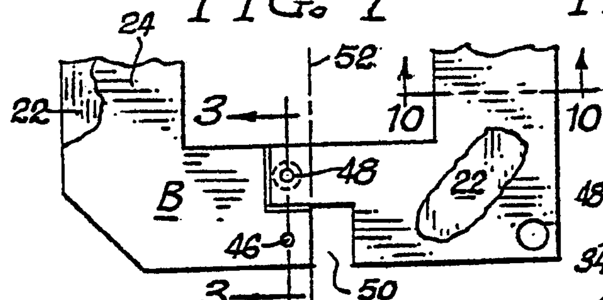

FIG. 3

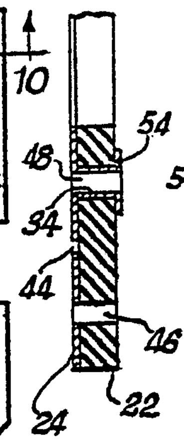

FIG. 9

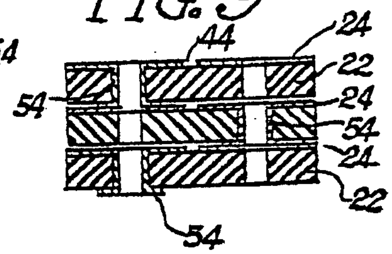

FIG. 8

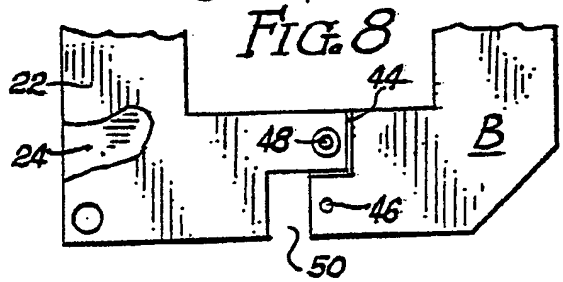

FIG. 4

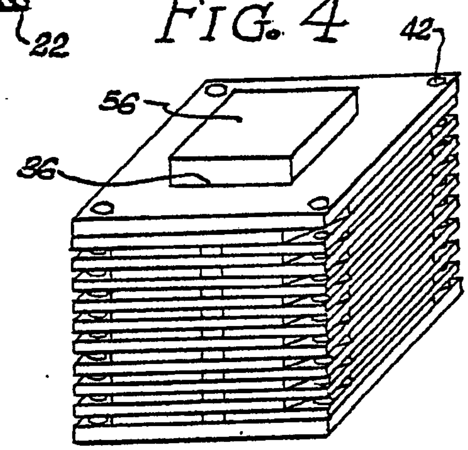

FIG. 10

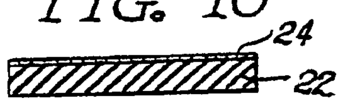

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FIG. 11

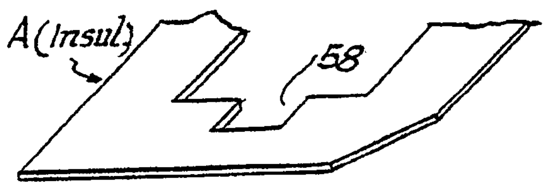


FIG. 12

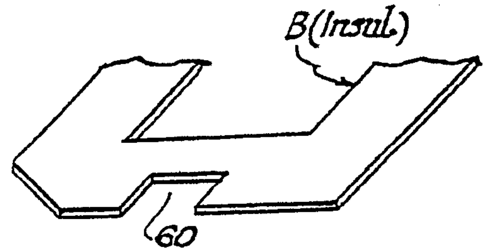


FIG. 13

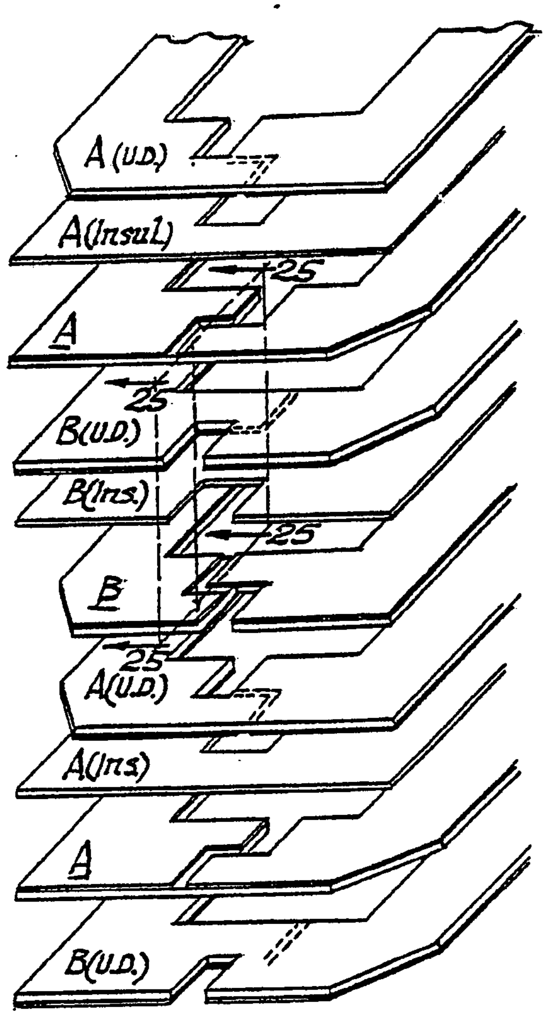


FIG. 14

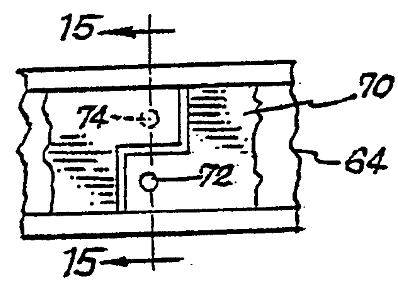


FIG. 15

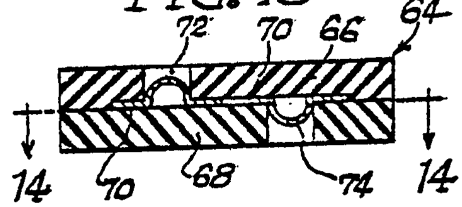


FIG. 16

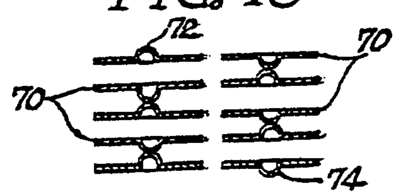


FIG. 25

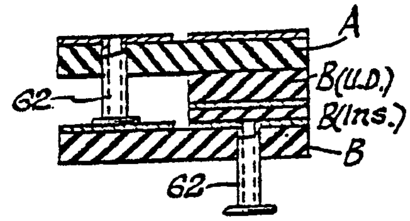


FIG. 17

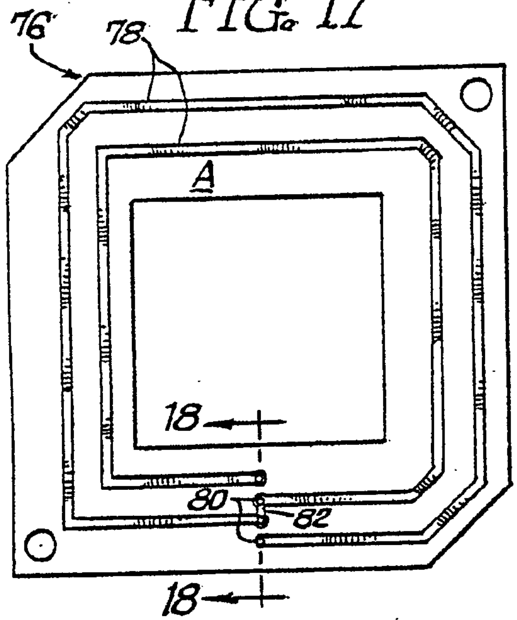


FIG. 18

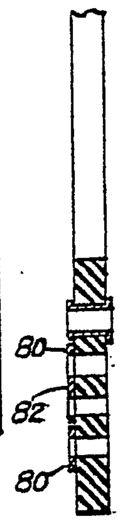


FIG. 21

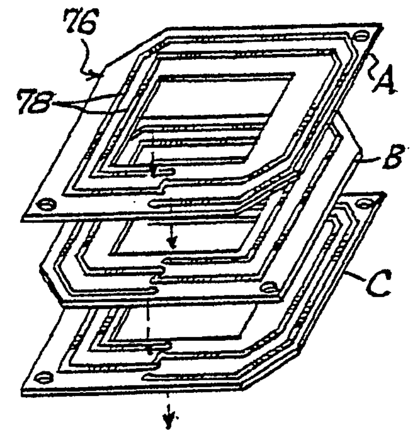


FIG. 19

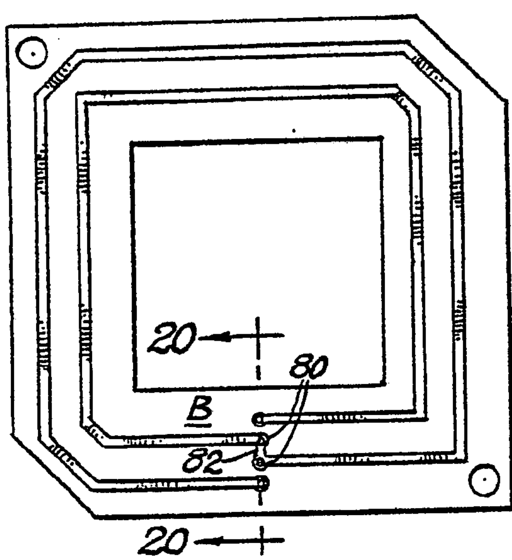


FIG. 20

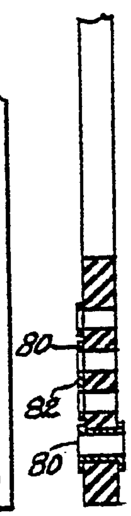


FIG. 22

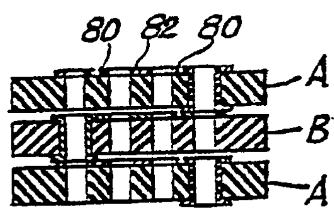


FIG. 24

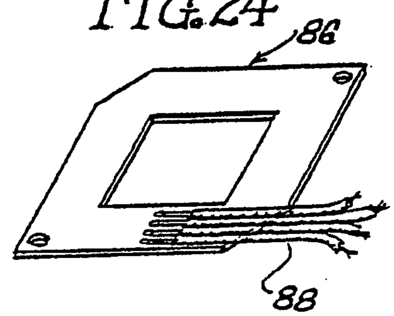
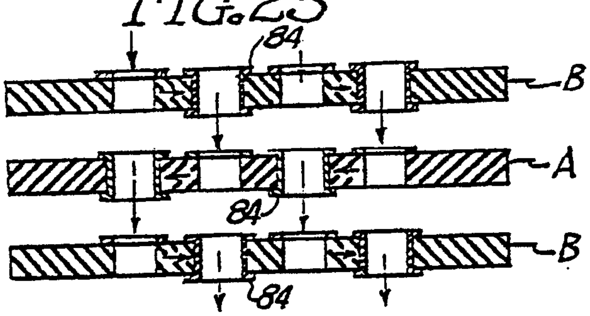


FIG. 23



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 82/00090

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. Cl. 3 H01F 5/00; H01F 27/30; H01G 1/005. US CL - 336/200 223, 232; 361/303

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	336/180, 200, 206, 221, 222, 223, 232; 361/303, 307; 338/314,320 306,

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 3,089,106, Published 7 May, 1963, Seaty	1,2,3,5,6
X	GB,A, 993,265, Published 26 May 1965, Inoue	1,2,3,5,6
X	US, A, 3,848,210, Published 12 November 1964, Felkner	15
A	G B, A, 772,528, Published 17 April 1957 Leno	1,2,3,5,8,9
A	FR, A, 2,379,229, Published 25 August 1978, Dubuisson	1-5
X	US, A, 3,812,442, Published 21 May 1974, Muckelroy	1,2,5
X	US, A, 3,833,872, Published 3 September 1974, Marcus et al	1,2,3,5
X	US, A, 3,798,059, Published 19 March 1974, Astle et al	1,2,3,5

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
23 April 1982	13 MAY 1982
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	T. J. Kozma

Form PCT/ISA/210 (second sheet) (October 1977)

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International Application No. PCT/US 82/00090

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A,P	US, A, 4,310,821 Published 12 January 1982, France	1-9
X	US, A, 3,011,106 Published 28 November 1961, Ducati	1,7
X	US, A, 4,115,833 Published 19 September 1978, Cirkel	1,7

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01733

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01F 27/32, H02K 3/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F, H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5036165 A (RICHARD K. ELTON ET AL), 30 July 1991 (30.07.91), abstract --	1
A	US 4109098 A (MATS GUNNAR OLSSON ET AL), 22 August 1978 (22.08.78), abstract -- --------	1

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 March 1999	01-04-1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Westöö Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/99

International application No.
PCT/SE 98/01733

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5036165 A	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
		US 4853565 A	01/08/89
US 4109098 A	22/08/78	AR 211382 A	15/12/77
		AU 7707175 A	08/07/76
		BE 825068 A	15/05/75
		BR 7500229 A	04/11/75
		CA 1038052 A	05/09/78
		CH 587545 A	13/05/77
		DE 2501811 A	14/08/75
		DK 32675 A	29/09/75
		FI 68477 B,C	31/05/85
		FI 750213 A	01/08/75
		FR 2260173 A,B	29/08/75
		GB 1493163 A	23/11/77
		JP 50109479 A	28/08/75
		NL 7501168 A	04/08/75
		SE 384420 B,C	03/05/76
		SE 7401244 A	01/08/75